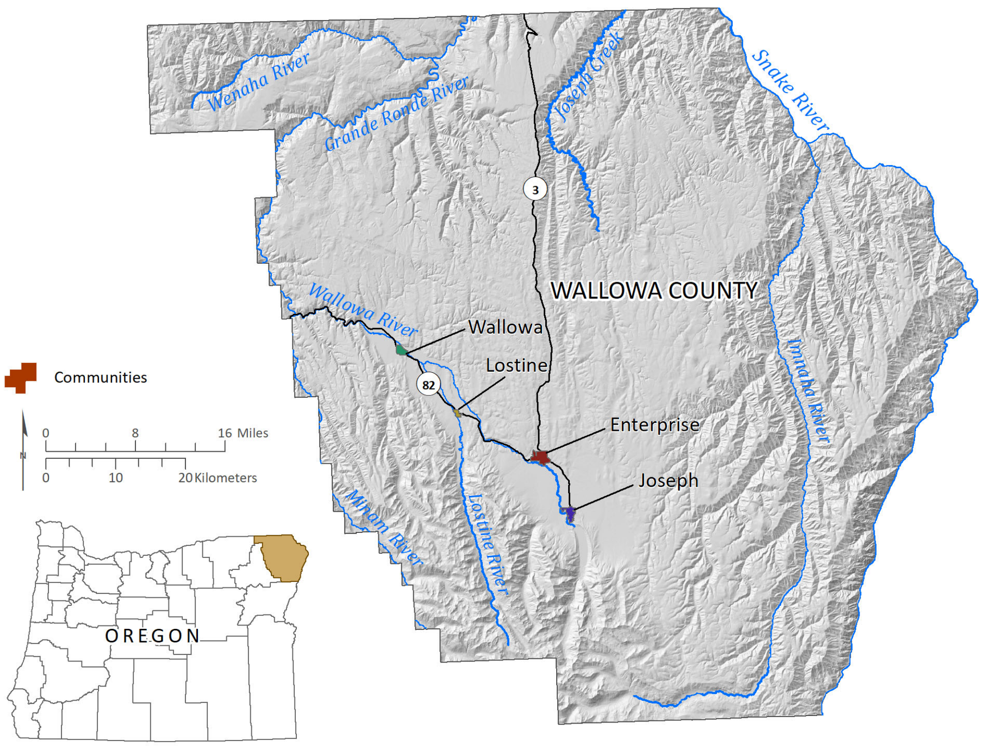
State of Oregon
Oregon Department of Geology and Mineral Industries
Sarah Lewis, Interim State Geologist

OPEN-FILE REPORT O-22-03

MULTI-HAZARD RISK REPORT FOR WALLOWA COUNTY, OREGON

INCLUDING THE CITIES OF ENTERPRISE, LOSTINE, JOSEPH, AND WALLOWA



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2022

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Cover image: Study area of the Wallowa County Risk Report. Map depicts Wallowa County, Oregon and incorporated communities included in this report.

WHAT'S IN THIS REPORT?

This report describes the methods and results of natural hazard risk assessments for Wallowa County communities. The risk assessments can help communities better plan for disaster.

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GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.7 format. Metadata is embedded in the geodatabase and is also provided as separate .xml format files.

Wallowa_County_Risk_Report_Data.gdb

Feature dataset: Asset_Data

feature classes:

- Building_footprints (polygons)
- Communities (polygons)
- UDF_points (points)

Wallowa_County_Depth_Grids.gdb

Raster data:

- FL_Depth_10yr
- FL_Depth_50yr
- FL_Depth_100yr
- FL_Depth_500yr

Metadata in .xml file format:

Each dataset listed above has an associated, standalone .xml file containing metadata in the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata format

EXECUTIVE SUMMARY

This report was prepared for the communities of Wallowa County, Oregon, with funding provided by the Oregon Department of Land Conservation and Development (DLCD). It describes the methods and results of natural hazard risk assessments performed in 2021 by the Oregon Department of Geology and Mineral Industries (DOGAMI). The purpose is to provide Wallowa County communities a detailed risk assessment of the natural hazards that affect them to enable them to compare hazards and act to reduce their risk. The risk assessment contained in this project quantifies the impacts of natural hazards to these communities and enhances the decision-making process in planning for disaster.

We arrived at our findings and conclusions by completing three main tasks: compiling an asset database, identifying and using best available hazard data, and performing natural hazard risk assessment.

In the first task, we created a comprehensive asset database for the entire study area by synthesizing assessor data, U.S. Census information, Hazus-MH general building stock information, and building footprint data. This work resulted in a single dataset of building points and their associated building characteristics. With these data we were able to represent accurate spatial location and vulnerability on a building-by-building basis.

The second task was to identify and use the most current and appropriate hazard datasets for the study area. Most of the hazard datasets used in this report were created by DOGAMI; some were produced using high-resolution lidar topographic data. While not all the data sources used in the report are countywide, each hazard dataset was the best available at the time of writing.

In the third task, we performed risk assessments using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using Federal Emergency Management Agency (FEMA) Hazus®-MH methodology, and (2) calculated number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides and wildfire.

The findings and conclusions of this report show the potential impacts of hazards in communities within Wallowa County. An earthquake can cause a moderate amount of damage and losses throughout the county. Hazus-MH earthquake simulations illustrate the potential reduction in earthquake damage through seismic retrofits. Some communities in the study area have significant risk from flooding, and we quantify the number of elevated structures that are less vulnerable to flood hazard. Our analysis shows that new landslide mapping based on improved methods and lidar information will increase the accuracy of mapping. Wildfire risk is high for the majority the unincorporated county, as well as parts of Enterprise and Wallowa. Our findings also indicate that many of the critical facilities in the study area are at high risk from wildfire hazard. We also found that the two biggest causes of population displacement are wildfire hazard. Lastly, we demonstrate that this risk assessment can be a valuable tool to local decision-makers.

Results were broken out for the following geographic areas:

- Unincorporated Wallowa County (rural)
- City of Joseph
- City of Wallowa
- City of Enterprise
- City of Lostine

Selected Countywide Results
Total buildings: 9,708
Total estimated building value: $910 million

2500-year Probabilistic Magnitude 7.0 Earthquake
Red-tagged buildings[a]: 497
Yellow-tagged buildings[b]: 1,515
Loss estimate: $114 million

100-year Flood
Number of buildings damaged: 295
Loss estimate: $1.5 million

Landslide (High and Very High-Susceptibility)
Number of buildings exposed: 568
Exposed building value: $67 million

Wildfire (High Risk):
Number of buildings exposed: 3,623
Exposed building value: $286 million

[a]Red-tagged buildings are considered uninhabitable due to complete damage
[b]Yellow-tagged buildings are considered limited habitability due to extensive damage

1.0 INTRODUCTION

A natural hazard is a naturally occurring phenomenon that can negatively impact humans. A natural hazard risk assessment analyzes impacts on the built environment and population. It also estimates the amount of losses and identifies potential risk. In natural hazard mitigation planning, risk assessments are the basis for developing mitigation strategies and actions. A risk assessment enhances the decision- making process, so that steps can be taken to prepare for a potential hazard event.

Key Terms:
- *Vulnerability:* Characteristics that make people or assets more susceptible to a natural hazard.
- *Risk:* Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard.

Wallowa County is situated in the northeastern corner of Oregon, between the Blue Mountains and the Snake River and is subject to natural hazards, including earthquake, riverine flooding, landslides, and wildfire. The County is sparsely populated, with small communities surrounded by rangeland and forestland in the unincorporated areas. This is the first natural hazard risk assessment analyzing individual buildings and resident population in Wallowa County. It is therefore the most detailed and comprehensive analysis to date of natural hazard risk and provides a comparative perspective never before available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to Wallowa County communities.

1.1 Purpose

The purpose of this project is to help Wallowa County communities better understand their risk and increase resilience to natural hazards. This is accomplished by providing accurate, detailed, and best available information about these hazards and by measuring the number of people and buildings at risk.
The main objectives of this study are to:

- compile and/or create a database of critical facilities, tax assessor data, buildings, and population distribution data,

- incorporate and use existing data from previous geologic, hydrologic, and wildfire hazard studies,
- perform exposure and Hazus–based risk analysis, and
- share this report widely so that all interested parties have access to its information and data.

The body of this report describes the methods and results for these objectives. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to analyze risk. Results for each hazard type are reported on a countywide basis within each hazard section, and community-based results are reported in detail in **Appendix A**. **Appendix B** contains detailed risk assessment tables. **Appendix C** is a more detailed explanation of the Hazus-MH methodology. **Appendix D** lists acronyms and definitions of terms used in this report. **Appendix E** contains tabloid-size county-wide hazard maps.

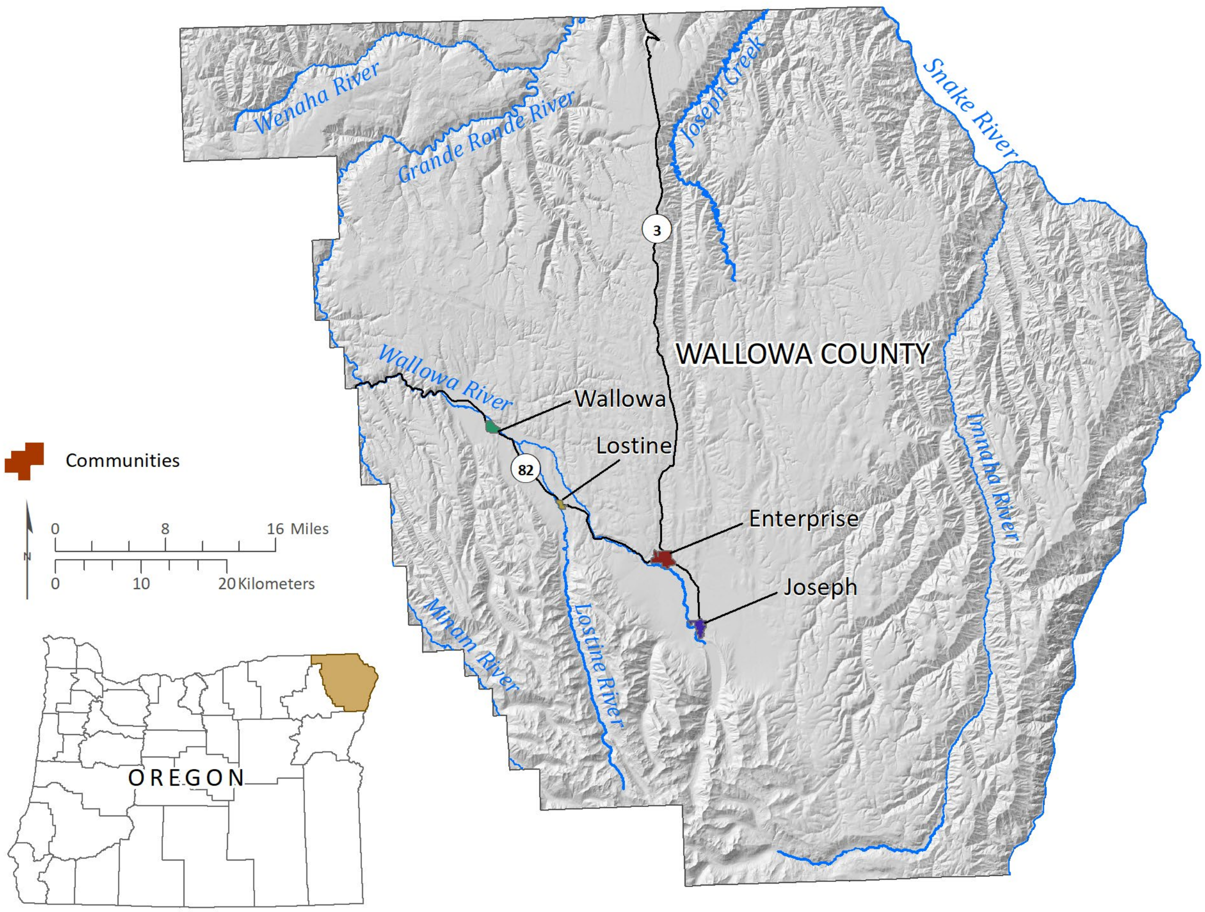
1.2 Study Area

The study area for this project is the entirety of Wallowa County, Oregon (**Figure 1-1**). Wallowa County is located in the northeastern corner of the state and is bordered by Baker County on the south, Union County on the west, Umatilla County on the northwest, the State of Washington on the north and the State of Idaho on the east. The study area covers approximately 3,152 square miles (8,164 square kilometers). The Wallowa-Whitman National Forest accounts for approximately 65% of the land ownership in Wallowa County.

The geography consists of the Columbia Plateau, bounded on the west by the rugged Wallowa Mountains and on the east by Hells Canyon of the Snake River. The Plateau is cut by steep canyons draining into the Snake River. The Plateau areas are a mix of forest and grasslands, and the Wallowa Mountains are forested with glaciated alpine areas at higher elevations. The Imnaha, Lostine, and Wallowa Rivers all originate within the Wallowa Mountains and drain to the Snake River.

The population of the County is 7,008 based on the 2010 U.S. Census Bureau (2010a). The county seat and county's largest community is the City of Enterprise. Most of the residents in the study area reside along the eastern base of the Wallowa Mountains and north of Wallowa Lake. The incorporated communities of the study area are Enterprise, Joseph, Lostine, and Wallowa (**Figure 1-1**). No unincorporated communities were individually examined in this study.

Figure 1-1. Study area: Wallowa County with communities in this study identified.



1.3 Project Scope

For this risk assessment, we applied a quantitative approach to buildings and population. We limited the project scope to buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not analyze impacts to the local economy, land values, or the environment. Depending on the natural hazard, we used one of two methodologies: loss estimation or exposure. Loss estimation was modeled using methodology from Hazus®-MH (FEMA, 2012a, 2012b, 2012c), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Exposure is a simpler methodology, where buildings are categorized based on their location relative to various hazard zones. To account for impacts on population (permanent residents only), city and county population numbers from the 2010 U.S. Census data (U.S. Census Bureau, 2010a) were distributed among residential buildings.

A critical component of this risk assessment is a countywide building inventory developed from building footprint data and the Wallowa County tax assessor database. The other key component is a suite of datasets that represent the currently best available science for a variety of natural hazards. The geologic hazard scenarios were selected by DOGAMI staff based on their expert knowledge of the datasets; most datasets are DOGAMI publications. In addition to geologic hazards, we included wildfire hazard in this risk assessment. The following is a list of the natural hazards and the risk assessment methodologies that were applied. See **Table 1-1** for data sources.

Earthquake Risk Assessment

- Hazus-MH loss estimation from a 2500-year probabilistic magnitude (Mw) 7.0 scenario

Flood Risk Assessment

- Hazus-MH loss estimation to four recurrence intervals (10%, 2%, 1%, and 0.2% annual chance)
- Exposure to 1% annual chance recurrence interval

Landslide Risk Assessment

- Exposure based on Landslide Susceptibility Index (low to very high)

Wildfire Risk Assessment

- Exposure based on Fire Risk Index (low to high)

Table 1-1. Hazard data sources for Wallowa County.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake (includes liquefaction and coseismic landslides)	2,500-year probabilistic Mw 7.0	Statewide	DOGAMI OSHD 1.0 (Madin and others, 2021)
Flood	Depth Grids: 10% (10-yr) 2% (50-yr) 1% (100-yr) 0.2% (500-yr)	Countywide	Wallowa County MHRA (2022) – derived from FEMA (1988) data
Landslide*	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI O-16-02 (Burns and others, 2016)
Wildfire	Risk (Low, Moderate, High)	Regional (Pacific Northwest, US)	ODF (Pyrologix, LCC, 2018)

*Landslide data comprise a composite dataset where the level of detail varies greatly from place to place within the state. Refer to Section 3.4.1 or the report by Burns and others (2016) for more information.

1.4 Previous Studies

One previous risk assessment has been conducted that included Wallowa County by DOGAMI. Wang (1998) used Hazus-MH to estimate the impact from a Mw 8.5 Cascade Subduction Zone (CSZ) earthquake scenario on the state of Oregon. The results of this study were arranged into individual counties. Wallowa County was estimated to experience less than a 1% loss ratio in the Mw 8.5 CSZ scenario, due to the great distance of the County from the offshore CSZ. We did not compare the results of this project with the results of this previous study since very different methodologies were used.

2.0 METHODS

2.1 Hazus-MH Loss Estimation

According to FEMA (FEMA, 2012a, p. 1), "Hazus provides nationally applicable, standardized methodologies for estimating potential wind, flood, and earthquake losses on a regional basis. Hazus can be used to conduct loss estimation for floods and earthquakes […]. The multi-hazard Hazus is intended for use by local, state, and regional officials and consultants to assist mitigation planning and emergency response and recovery preparedness. For some hazards, Hazus can also be used to prepare real-time estimates of damages during or following a disaster."

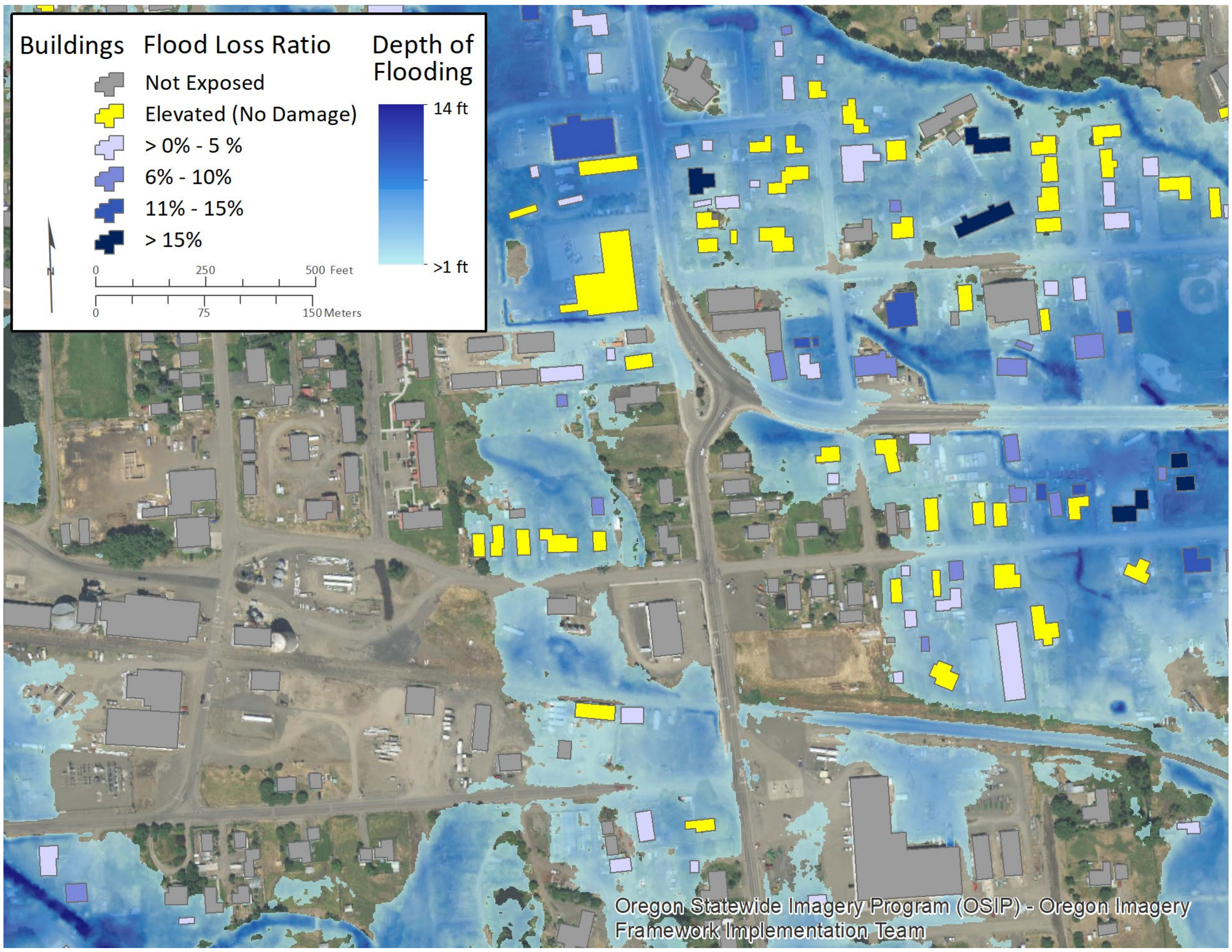
> ***Key Terms:***
> - *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology.
> - *Loss ratio:* Percentage of estimated loss relative to the total value.

Hazus-MH can be used in different modes depending on the level of detail required. Given the high spatial precision of the building inventory data and quality of the natural hazard data available for this study, we chose the user-defined facility (UDF) mode. This mode makes loss estimates for individual buildings relative to their "cost," which we then aggregate to the community level to report loss ratios. Cost used in this mode are associated with rebuilding using new materials, also known as replacement cost. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus-MH database.

Damage functions are at the core of Hazus-MH. The damage functions stored within the Hazus-MH data model were developed and calibrated from the observed results of past disasters. Estimates of loss are made by intersecting building locations with natural hazard layers and applying damage functions based on the hazard severity and building characteristics. **Figure 2-1** illustrates the range of building loss estimates from Hazus-MH flood analysis.

We used Hazus-MH version 4.2, which was the latest version available when we began this risk assessment.

Figure 2-1. 100-year flood zone and building loss estimates example in City of Enterprise, OR.



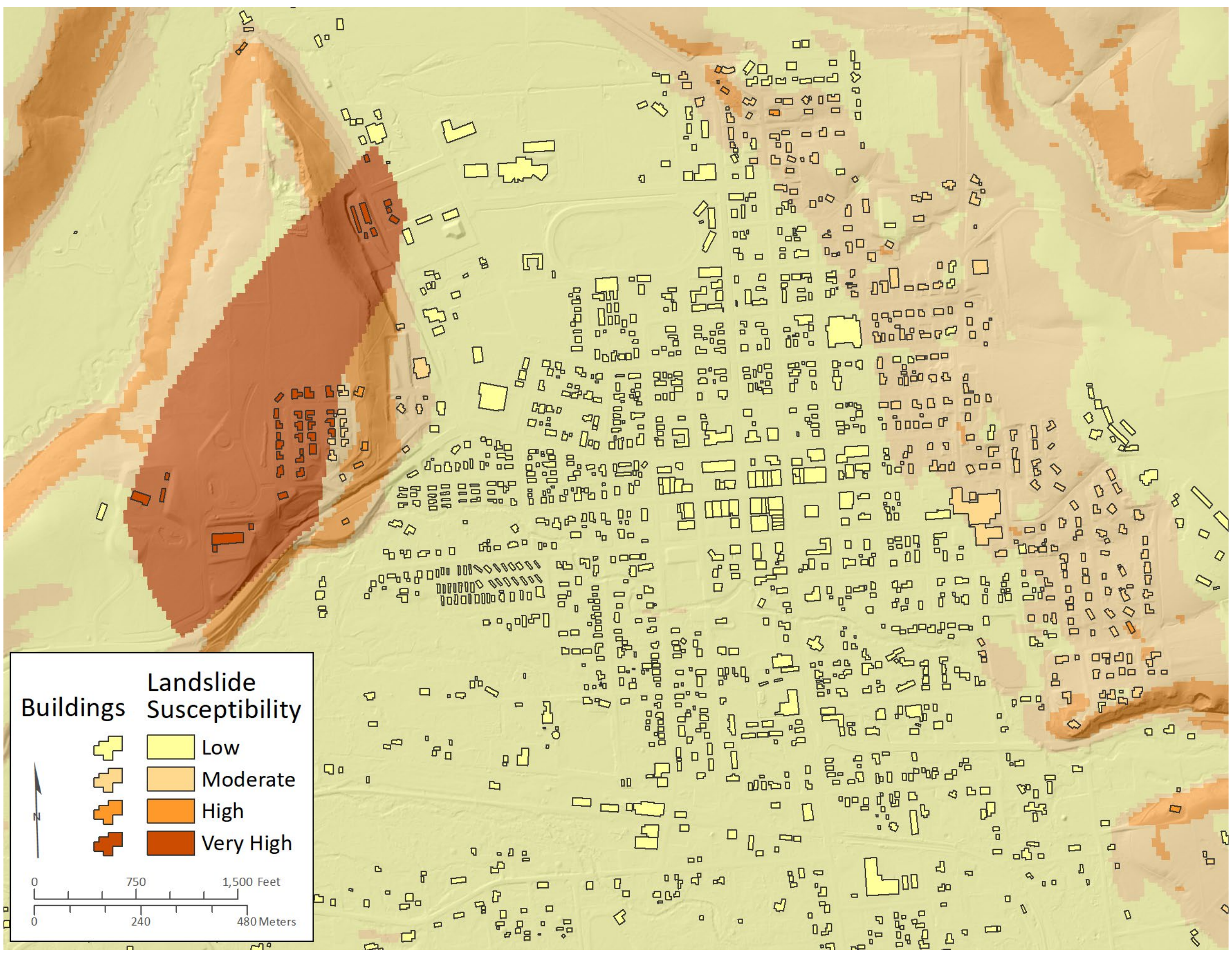
2.2 Exposure

> ***Key Terms:***
> - *Exposure:* Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.
> - *Building value:* Total monetary value of a building. This term is used in the context of exposure.

Exposure methodology identifies the buildings and population that are within a particular natural hazard zone. This is an alternative for natural hazards that do not have readily available damage functions to relate damage to the intensity of the hazard. It provides a way to easily quantify what is and what is not threatened. Exposure results are communicated in terms of total building value exposed, rather than a loss estimate because without a damage function a loss ratio cannot be calculated. For example, **Figure 2-2** shows buildings that are exposed to different areas of landslide susceptibility.

Exposure is used for landslides and wildfires. For comparison with loss estimates, exposure is also used for the 1% annual chance flood.

Figure 2-2. Landslide susceptibility areas and building exposure example in the City of Enterprise, OR.



2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 200 square feet (19 square meters), as determined from existing building footprints (Williams, 2021). **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Wallowa County. See also **Appendix B** Table B-1, and **Appendix E**, Plate 1 and Plate 2.

To use the building inventory within the Hazus-MH methodology, we converted the building footprints to points and migrated them into a UDF database with standardized field names and attribute domains. The UDF database formatting allows for the correct damage function to be applied to each building. Hazus-MH version 2.1 technical manuals (FEMA, 2012a, 2012b, 2012c) provide references for acceptable field names, field types, and attributes. The fields and attributes used in the UDF database (including building seismic codes) are discussed in more detail in Appendix **C.2.2**.

Figure 2-3. Building occupancy types, City of Enterprise, Oregon.

Table 2-1 shows the distribution of building count and value within the UDF database for Wallowa County. A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

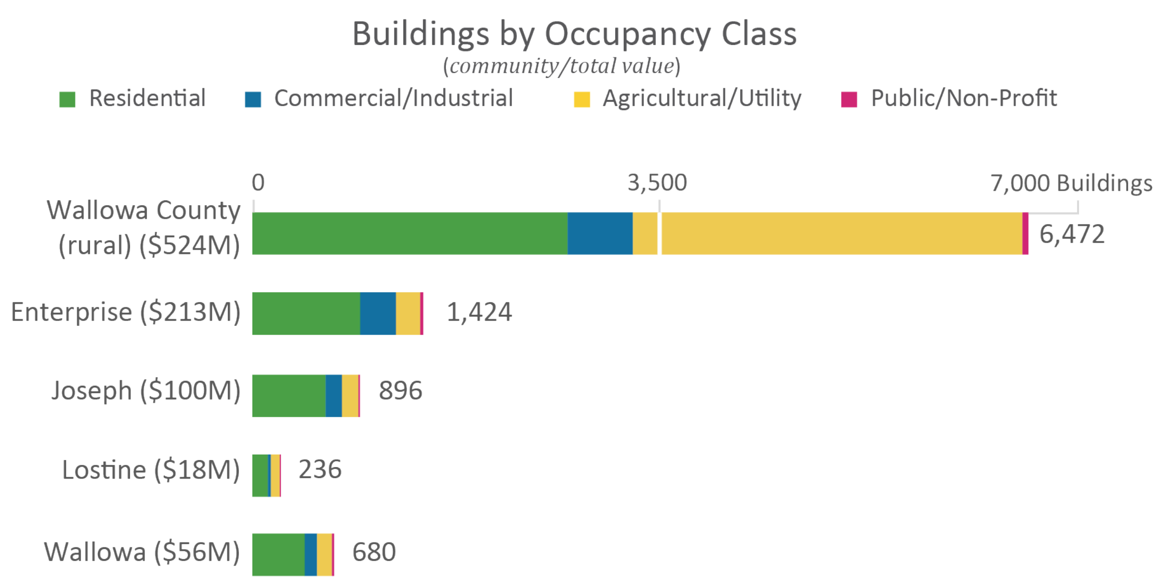
Table 2-1. Wallowa County building inventory.

Community	Total Number of Buildings	Percentage of Total Buildings	Estimated Total Building Value ($)	Percentage of Total Building Value
Unincorp. Wallowa Co (rural)	6,472	67%	523,679,000	58%
Enterprise	1,424	15%	212,587,000	23%
Joseph	896	9.2%	99,947,000	11%
Lostine	236	2.4%	17,930,000	2.0%
Wallowa	680	7.0%	55,658,000	6.1%
Total Wallowa County	9,708	100%	909,800,000	100.0%

The building inventory was developed from a building footprint dataset developed in 2021 called the Statewide Building Footprints for Oregon, release 1 (SBFO-1) (Williams, 2021), which covers all of Wallowa County. The building footprints provide a location and 2D outline of a structure. The total number of buildings within the study area was 9,703. A small number of buildings were added to this data, particularly, the recently built, 8,600 square foot Sports Complex in Enterprise.

Wallowa County supplied assessor data and it was formatted for use in the risk assessment. The assessor data contains an array of information about each building (i.e., improvement). Tax lot data, which contains property boundaries and other information about the property, was obtained from the county assessor and was used to link the buildings with assessor data. The linkage between the two datasets resulted in a database of UDF points that contain attributes for each building. These points are used in the risk assessments for both loss estimation and exposure analysis. **Figure 2-4** illustrates the building value and occupancy class across the communities of Wallowa County.

Figure 2-4. Community building value in Wallowa County by occupancy class.



We attributed critical facilities in the UDF database so that they could be highlighted in the results. Critical facilities data came from the DOGAMI Statewide Seismic Needs Assessment (SSNA; Lewis, 2007). We updated the SSNA data through consultation with Wallowa County, which provided a list of critical facilities with corresponding addresses. The critical facilities we attributed include hospitals, schools, fire stations, police stations, emergency operations, and military facilities. In addition to these standard building types, we considered other building types based on local input or special considerations that are specific to the study area that would be essential during a natural hazard event, such as public works and water treatment facilities. Critical facilities are important to note because these facilities play a crucial role in emergency response efforts. Communities that have critical facilities that can function during and immediately after a natural disaster are more resilient than those with critical facilities that are inoperable after a disaster. Critical facilities are shown by community in **Table 2-2** and are listed for each community in **Appendix A**.

Table 2-2. Wallowa County critical facilities inventory.

	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
Community	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
(all dollar amounts in thousands)														
Unincorp. Wallowa Co (rural)	0	0	2	392	2	2,868	0	0	0	0	12	10,489	16	13,749
Enterprise	1	31,878	2	5,571	1	1,765	1	573	0	0	8	8,820	13	48,607
Joseph	0	0	1	8,303	1	120	0	0	0	0	1	355	3	8,778
Lostine	0	0	0	0	1	71	0	0	0	0	3	164	4	235
Wallowa	0	0	1	6,375	1	199	0	0	0	0	2	406	4	6,980
Total Wallowa County	1	31,878	6	20,642	6	5,022	1	573	0	0	26	20,234	40	78,349

Note: Facilities with multiple buildings were consolidated into one building.

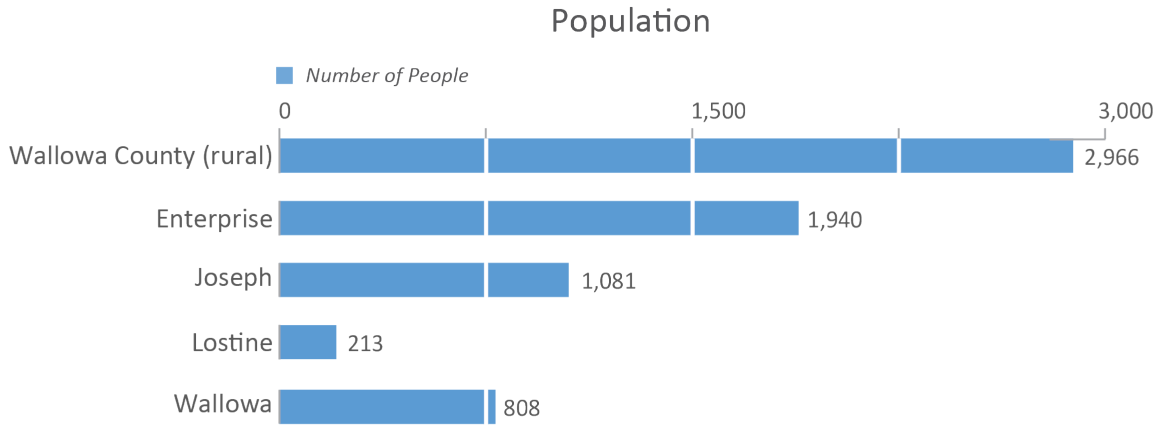
* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

2.4 Population

Within the UDF database, the population of permanent residents reported per census block was distributed among residential buildings and pro-rated based on square footage (**Figure 2-5**). We did not examine the impacts of natural hazards on non-permanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, the distribution includes vacation homes, which in many communities make up some of the total residential building stock. From information reported in the 2010 U.S. Census, American FactFinder regarding vacation rentals within the county, it is estimated that approximately 20% of residential buildings are vacant in Wallowa County and a significant portion of these could be vacation rentals (U.S. Census Bureau, 2010b).

From the 2010 census, we analyzed the 7,008 residents within the study area that could be affected by a natural hazard scenario. While current estimates of population are higher overall for the county, the percent of displaced population results would only be slightly affected. For each natural hazard, except for the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population by Wallowa County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers four natural hazards (earthquake, flood, landslide, and wildfire) that pose a risk to Wallowa County. The assessment describes both localized vulnerabilities and the widespread challenges that impact all communities. The loss estimation and exposure results, as well as the rich dataset included with this report, can lead to greater understanding of the potential impact of disasters. Communities can use the results to update plans as part of the work toward becoming more resilient to future disasters.

3.1 Hazards and Countywide Results

In this section, results are presented for Wallowa County. Individual community results are in **Appendix A: Community Risk Profiles**.

3.2 Earthquake

An earthquake results from a sudden movement of rock on each side of a fault in the earth's crust that abruptly releases strain accumulated over a long period of time. The movement along the fault produces waves of strong shaking that spread in all directions. If an earthquake occurs near populated areas, it may cause causalities, economic disruption, and extensive property damage (Madin and Burns, 2013).

Two earthquake-induced hazards are liquefaction and coseismic landslides. Liquefaction occurs when saturated soils substantially lose bearing capacity due to ground shaking, causing the soil to behave like a liquid; this action can be a source of tremendous damage. Coseismic landslides are mass movement of rock, debris, or soil induced by ground shaking. All earthquake loss estimates in this report include damage derived from shaking and from liquefaction and landslide factors.

3.2.1 Data sources

Hazus-MH offers two scenario methods for estimating loss from earthquakes, probabilistic and deterministic (FEMA, 2012b). A probabilistic scenario uses U.S. Geological Survey (USGS) National Seismic Hazard Maps which are derived from seismic hazard curves calculated on a grid of sites across the United States that describe the annual frequency of exceeding a level of ground motion as a result of all possible earthquake sources (USGS, 2017). A deterministic scenario is based on a specific seismic event, such as a Cascadia Subduction Zone magnitude 9.0 event. We used the probabilistic scenario method for this study because the probabilistic approach accounts for the great uncertainty about earthquake sources in the area.

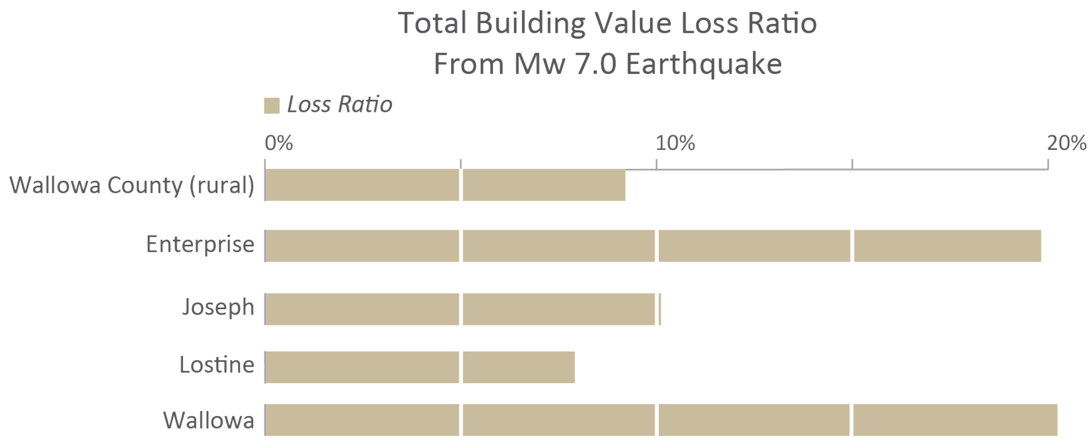
The 2% in 50 years or 2,475-year probabilistic shaking map of Madin and others (2021) was selected as the most appropriate for communicating earthquake risk for Wallowa County. We based this decision on several factors such as previous Hazus-MH earthquake analyses in the region, available seismic data (historical events, fault locations, etc.), and existing building code standards. It is important to note that the probabilistic shaking map is based on the highest level of shaking that could reasonably be expected to occur on average once every 2,475 years. For practical purposes it can be considered a worst-case event for each community, although it does not represent shaking that would impact the entire County in a single earthquake. The probabilistic earthquake results should be used carefully for risk assessment and emergency response planning purposes.

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate the probability and magnitude of permanent ground deformation caused by these factors. Although the probabilistic shaking map encompasses all possible earthquake sources, Hazus uses a characteristic magnitude value to calculate the impacts of liquefaction and landslides. For this study, we followed the example of Madin and others (2021) and used Mw 7 as the characteristic event.

3.2.2 Countywide results

Because an earthquake can affect a wide area, it is unlike other hazards in this report—every building in Wallowa County is exposed to significant probabilistic shaking hazard (though not necessarily simultaneously). Hazus-MH loss estimates (see **Appendix B** Table B-2) for each building are based on a formula where coefficients are multiplied by each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios that are then multiplied by the total building replacement value to obtain a loss estimate (FEMA, 2012b). **Figure 3-1** shows the estimated loss ratios by community for Wallowa County from the earthquake scenario described in this report.

Figure 3-1. Earthquake loss ratio by Wallowa County community.



In keeping with earthquake damage reporting conventions, we used the ATC-20 post-earthquake building safety evaluation color-tagging system to represent damage states (Applied Technology Council, 2015). Red-tagged buildings correspond to a Hazus-MH damage state of "complete," which means the building is uninhabitable. Yellow-tagged buildings are in the "extensive" damage state, indicating limited habitability. The number of red or yellow-tagged buildings we report for each community is based on an aggregation of the probabilities for individual buildings (FEMA, 2012b).

Critical facilities were considered non-functioning if the Hazus-MH earthquake analysis showed that a building or complex of buildings had a greater than 50-percent chance of being at least moderately damaged (FEMA, 2012b). Because building specific information is more readily available for critical facilities and due to their importance after a disaster, we chose to report the results of these buildings individually.

The number of potentially displaced residents from an earthquake scenario described in this report was based on the formula: ([Number of Occupants] * [Probability of Complete Damage]) + (0.9 * [Number of Occupants] * [Probability of Extensive Damage]) (FEMA, 2012b). The probability of damage state was determined in the Hazus-MH earthquake analysis results.

Wallowa County 2,500-year probabilistic Mw 7.0 earthquake results:

- Number of red-tagged buildings: 497
- Number of yellow-tagged buildings: 1,515
- Loss estimate: $114,111,000
- Loss ratio: 13%
- Non-functioning critical facilities: 19
- Potentially displaced population: 576

The results indicate that Wallowa County could incur a moderate level of losses (13%) due to the earthquakes represented in the probabilistic shaking map. These results are strongly influenced by ground deformation from liquefaction. Moderate to high liquefaction susceptibility exists in the valley along the Wallowa River, which increases the risk from earthquake. Developed areas in the communities of Enterprise, Joseph, Lostine, and Wallowa that are built on highly liquefiable soils have higher estimates of damage from this earthquake scenario than rural parts of the county.

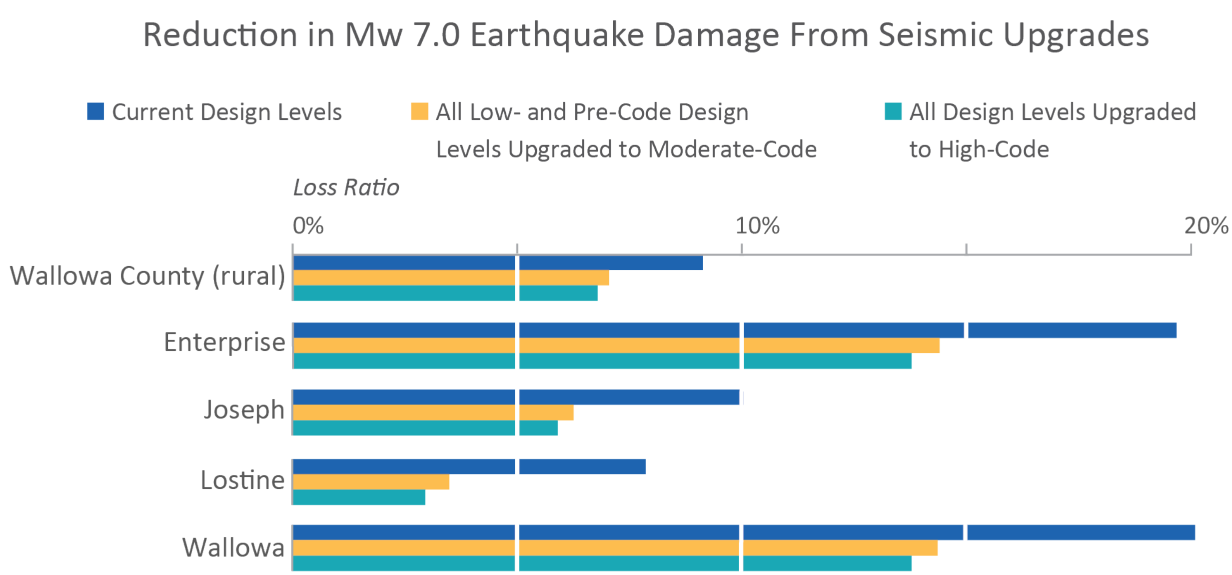
Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a small amount of the estimated damage from the earthquake hazard in Wallowa County. Landslide exposure results show that 7% of buildings in Wallowa County are within a very high or high susceptibility zone. This indicates that a similar percentage of the earthquake loss estimated in this study may be due to coseismic landslide.

Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in loss estimates. The first seismic buildings codes were implemented in Oregon in the 1970's (Judson, 2012) and by the 1990's modern seismic building codes were being enforced. Nearly 75% of Wallowa County's buildings were built before the 1990's. In Hazus-MH, manufactured homes are one occupancy type that performs poorly in earthquake damage modeling. Communities that are composed of an older building stock and more vulnerable occupancy types are expected to experience more damage from earthquake than communities with fewer of these vulnerabilities.

If buildings could be seismically retrofitted to higher code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that loss ratios drop from 13% to 9.2%, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, for areas of high landslide or liquefaction, additional geotechnical mitigation may be necessary to have an effect on losses. **Figure 3-2** illustrates the reduction in loss estimates from the probabilistic Mw 7.0 earthquake through two simulations where all buildings are upgraded to moderate code standards or to high code standards.

> ***Key Terms:***
> - *Seismic retrofit:* Structural modification to a building that improves its resilience to earthquake.
> - *Design level:* Hazus-MH terminology referring to the quality of a building's seismic building code (i. e. pre, low, moderate, and high). Refer to **Appendix C.2.3**for more information.

Figure 3-2. 2,500-year probabilistic Mw 7.0 earthquake loss ratio in Wallowa County, with simulated seismic building code upgrades.



3.2.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to earthquake hazard:

- High liquefaction areas in Wallowa County correspond to populated areas along the Wallowa River. Over 60% of the residents of Wallowa County have homes built on high liquefaction potential soils, which increases the likelihood of substantial ground deformation and building damage from an earthquake.
- Many high value buildings in commercial areas in Enterprise and Wallowa are unreinforced masonry buildings which are highly susceptible to damage from ground shaking.
- Based on the assessor's data used in this study, many buildings throughout the county are older and less likely to meet modern building design standards. Older buildings may be more vulnerable to substantial damage during an earthquake.
- 19 of the 40 critical facilities in the study area are estimated to be non-functioning due to an earthquake like the one simulated in this study.

3.3 Flooding

In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Floods are a commonly occurring natural hazard in Wallowa County and have the potential to create public health hazards and public safety concerns, close and damage major highways, destroy railways, damage structures, and cause major economic disruption. Flood issues like flash flooding, ice jams, post-wildfire floods, and dam safety were not examined in this report.

Floods vary greatly in size and duration, with smaller floods more likely than larger floods. A typical method for determining flood risk is to identify the size of a flood that has a particular probability of occurrence. This report uses floods that have an annual probability of occurrence of 10%, 2%, 1%, and 0.2%, henceforth referred to as 10-year, 50-year, 100-year, and 500-year scenarios, respectively. The size of floods estimated at these probabilities is based on a computer model that is based on recorded precipitation and stream levels.

The major streams within the county are the Grande Ronde, Imnaha, Lostine, Minam, Snake, Wallowa, and Wenaha Rivers and Joseph Creek. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain.

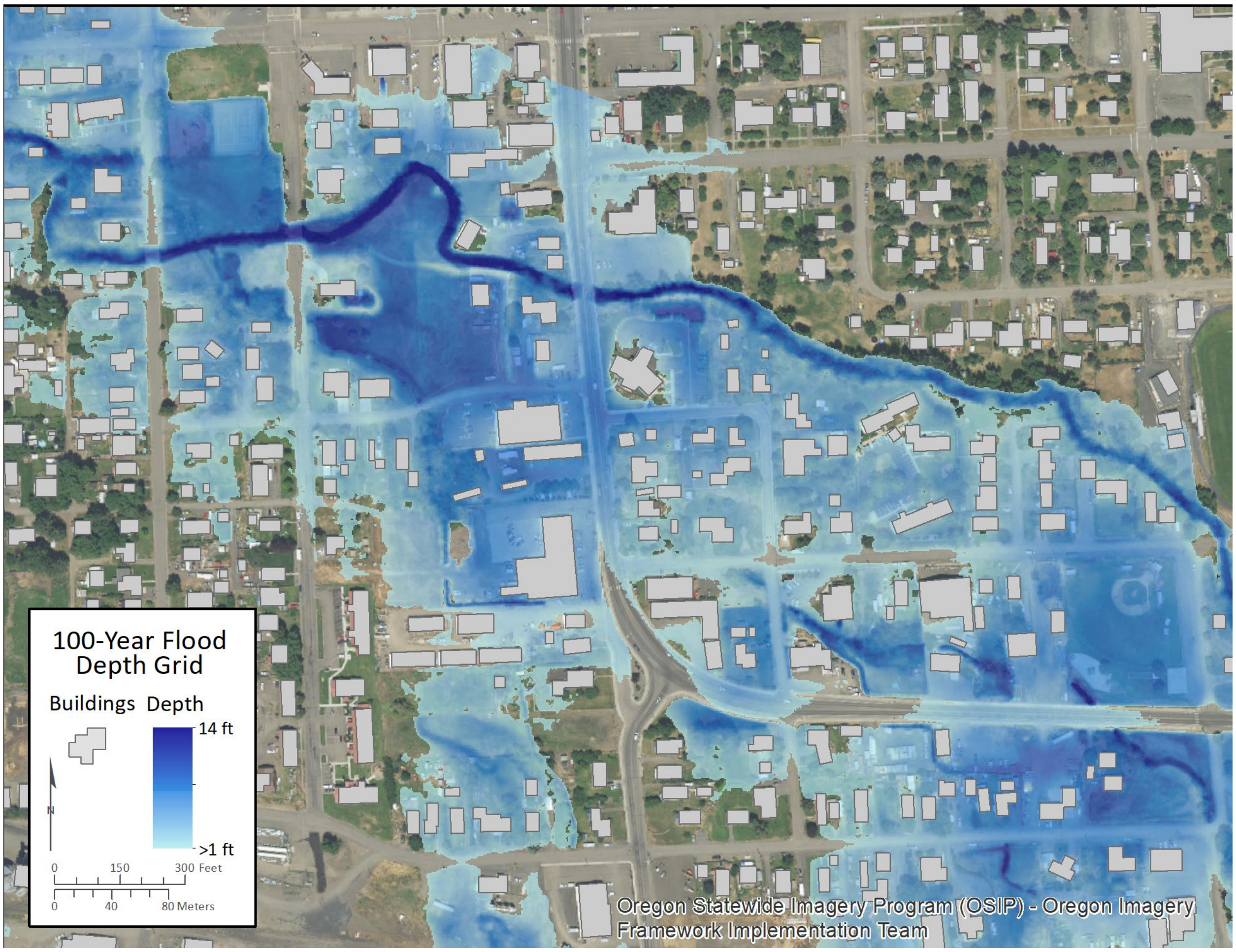
Floods commonly adversely impact human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are elevating structures above the expected level of flooding or removing the structure through FEMA's property acquisition ("buyout") program.

3.3.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for the study area were updated and made effective in 1988 (FEMA, 1988); these were the primary data sources for the flood risk assessment. Further information regarding NFIP related statistics can be found at FEMA's website: https://nfipservices.floodsmart.gov/reports-flood-insurance-data. These were the only flood data sources that we used in the analysis, but flooding does occur in areas outside of the detailed mapped areas. Over the 35 years since stream modeling first occurred in Wallowa County, the stream condition may have changed considerably and inaccuracies in the flood maps could be present.

We developed 10-, 50-. 100-, and 500-year flood depth maps from detailed stream model information within the study area. A flood depth map is a raster map of water depth for a specific flood in which each pixel value represents the depth of flooding at that location for a given flood (**Figure 3-3**). The flood depth maps are the result of subtracting the ground surface elevation represented by a detailed lidar DEM from a model of the water surface elevation for each flood. The flood depth maps were used in this risk assessment for loss estimations and, for comparative purposes, exposure analysis to determine the level of impact to people and buildings. The DEM that we used to create the flood depth maps was from high-resolution lidar collected in 2015 (Wallowa 3DEP project, Oregon Lidar Consortium; see http://www.oregongeology.org/lidar/collectinglidar.htm).

Figure 3-3. Flood depth grid example in the City of Enterprise, OR.



Building loss estimates are determined in Hazus-MH by overlaying building data on a depth map. Hazus-MH uses individual building information, specifically the first-floor height above ground and the presence of a basement, to calculate the loss ratio from a particular depth of flood.

For Wallowa County, occupancy type and basement presence attributes were available from the assessor database for most buildings. Where individual building information was not available from assessor data, we used oblique imagery and street level imagery to estimate these important building attributes. Only buildings in a flood zone or within 500 feet (152 meters) of a flood zone were examined closely to attribute buildings with more accurate information for first-floor height and basement presence. Because our analysis accounted for building first-floor height, buildings that have been elevated above the flood level were not given a loss estimate—but we did count residents in those structures as displaced. We did not look at the duration that residents would be displaced from their homes due to flooding. For information about structures exposed to flooding but not damaged, see the **Exposure analysis** section below.

3.3.2 Countywide results

For this risk assessment, we imported the countywide UDF data and depth grids into Hazus-MH and ran a flood analysis for four flood scenarios (10-, 50-, 100-, and 500-year). We used the 100-year flood scenario as the primary scenario for reporting flood results (also see **Appendix E** Plate 4). The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability that FEMA uses for regulatory purposes. See **Appendix B** Table B-4 for multi-scenario cumulative results.

Wallowa Countywide 100-year flood loss:

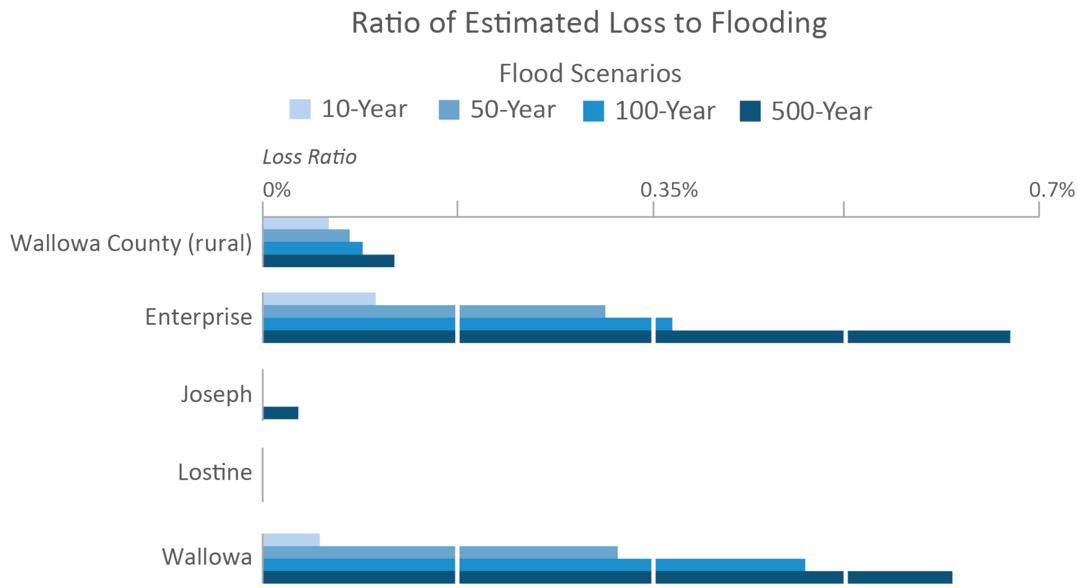
- Number of buildings damaged: 295
- Loss estimate: $1,547,000
- Loss ratio: 0.2%
- Non-functioning critical facilities: 0
- Potentially displaced population: 622

3.3.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is over $1.5 million. While the overall loss ratio for flood damage in Wallowa County is 0.2%, 100-year flooding has a significant impact to Wallowa County where development exists near streams (**Figure 3-4**). In communities where most residents are not within flood designated zones, the loss ratio may not be as helpful as the actual replacement cost and number of residents displaced to assess the level of risk from flooding. The Hazus-MH analysis also provides useful flood data on individual communities so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Wallowa County are found in the City of Enterprise in the designated 100-year floodplain. The Wallowa River and some of its tributaries could produce shallow flooding for a wide area in the southern portion of the City of Enterprise. Other communities, such as Joseph and Lostine, are estimated to have little to no damages from flooding (**Figure 3-4**). There are few areas of concentrated flood damage in the study area. The small amount of damage that is estimated is scattered across the county at various places along the mapped streams.

Figure 3-4. Ratio of flood loss estimates by Wallowa County community.



3.3.4 Exposure analysis

Separate from the Hazus-MH flood analysis, we did an exposure analysis by overlaying building locations on the 100-year flood extent. We did this to estimate the number of buildings that are elevated above the level of flooding and the number of displaced residents, both of which are not considered in the Hazus analysis. This was done by comparing the number of non-damaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. Some (5%) of Wallowa County's buildings were found to be within designated flood zones. Of the 486 buildings that are exposed to flooding, we estimate that 191 are above the height of the 100-year flood. This evaluation also estimates that 622 residents might have mobility or access issues due to surrounding water. See **Appendix B** Table B-5 for community-based results of flood exposure.

3.3.5 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to flood hazard:

- A wide area of buildings in the southern portion of Enterprise are at risk to exposure from shallow flooding.
- A few buildings along the Wallowa River in the City of Wallowa have the potential to be damaged by a 100-year flood.
- Updated stream modeling and flood mapping would provide a better understanding of the risk in Wallowa County.

3.4 Landslide Susceptibility

Landslides are mass downhill movements of rock, debris, or soil. There are many different types of landslides in Oregon. In Wallowa County, the most common are debris flows and shallow- and deep-seated landslides. Landslides can occur in many sizes, at different depths, and with varying rates of movement. Generally, they are large, deep, and slow moving or small, shallow, and rapid. Some factors that influence landslide type are hillside slope, water content, and geology. Many triggers can cause a landslide: intense rainfall, earthquakes, or human-induced factors like excavation along a landslide toe or loading at the top. Landslides can cause severe damage to buildings and infrastructure. Fast-moving landslides may pose life safety risks and can occur throughout Oregon (Burns and others, 2016).

3.4.1 Data sources

The Statewide Landslide Information Layer for Oregon [SLIDO], release 3.2 (Burns and Watzig, 2014) is an inventory of mapped landslides in the state of Oregon. SLIDO is a compilation of past studies; some studies were completed very recently using new technologies, like lidar-derived topography, and some studies were performed more than 50 years ago. Consequently, SLIDO data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state. Some landslide mapping for Wallowa County was done in 1979 and again in 2006 before lidar was available for high-accuracy mapping.

Burns and others (2016) used SLIDO inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns and others, 2016). Statewide landslide susceptibility map data have the inherent limitations of SLIDO and of the generalized geology and slope maps used to create the map. Therefore, the statewide landslide susceptibility map varies significantly in quality across the state, depending on the quality of the input datasets. Another limitation is that susceptibility mapping does not include some aspects of landslide hazard, such as runout, where the momentum of the landslide can carry debris beyond the zone deemed to be a high hazard area.

We used the data from the statewide landslide susceptibility map (Burns and others, 2016) in this report to identify the general level of susceptibility of given area to landslide hazards, primarily shallow and deep landslides. We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure for each community (see **Appendix B** Table B-6). We combined high and very high susceptibility zones to provide a general sense of community risk for planning purposes (see **Appendix E**, Plate 5).

The total dollar value of exposed buildings was summed for the study area and is reported below. We also estimated the number of people threatened by landslides. Land value losses due to landslides and potentially hazardous unmapped areas that may pose real risk to communities were not examined for this report.

3.4.2 Countywide results

The landslide exposure results are tabulated below for the high and very high categories and shown for all categories in **Figure 3-5**. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

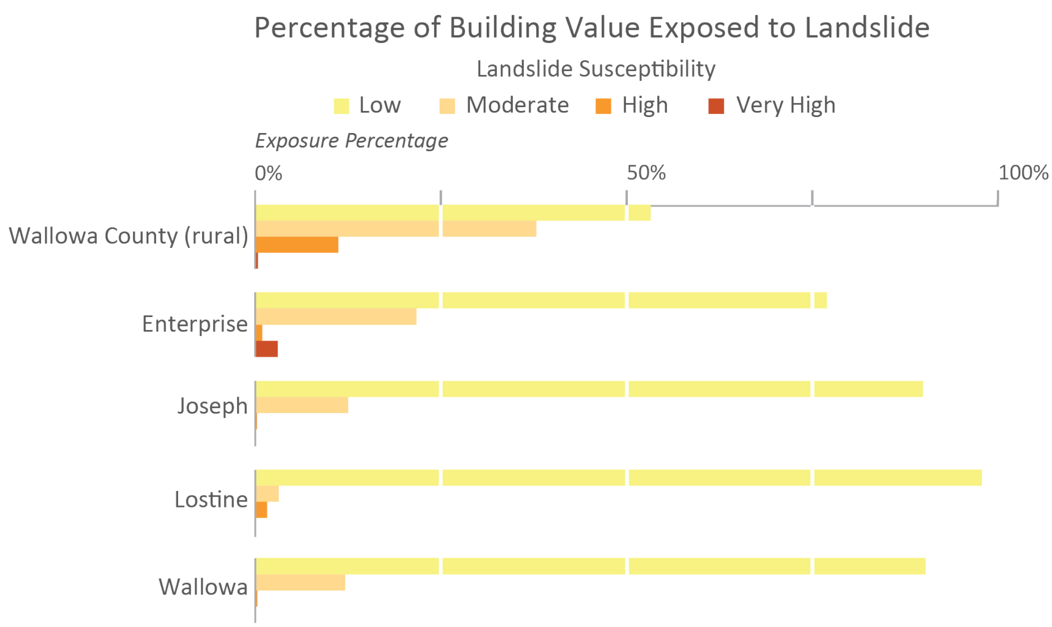
Wallowa Countywide landslide exposure (High and Very High susceptibility):

- Number of buildings: 568
- Value of exposed buildings: $67,445,000
- Percentage of total county value exposed: 7.4%
- Critical facilities exposed: 4
- Potentially displaced population: 248

Overall, the amount of exposure to landslide hazard in the county is small, with only 7% of building value exposed to high or very high susceptibility. Buildings throughout the rural parts of the county show a higher level of risk to landslide than urbanized areas.

Most of the developed land in Wallowa County is located on the flat terrain found in the river valleys which are typically low landslide susceptibility zones. Throughout rural portions of the county where buildings are present on steep hillsides the risk to landslide is greater. Landslide hazard is ubiquitous in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for every community and rural area of Wallowa County. A complete lidar-based landslide inventory for the County would provide much more accurate and detailed results.

Figure 3-5. Landslide susceptibility exposure by Wallowa County community.



3.4.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to landslide hazard:

- The current mapping show exposure to landslide hazard throughout rural parts of the county and along the base of the Wallowa Mountains.
- Some communities in Wallowa County may be at higher or lower risk than what the data show, due to very incomplete mapping of landslides.

3.5 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property in many communities. The most common severe wildfire conditions include: hot, dry, and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, its behavior is influenced by numerous conditions, including fuel, topography, weather, drought, and development (Pyrologix LCC, 2018). Post-wildfire geologic hazards can also present risk. These usually include flood, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

The Wallowa County Land Development Ordinance (WCLDO), from 1995, recommends that the county develop policies that address fire restriction enforcement, wildland urban interface standards, and building code enforcement related to emergency access (Wallowa County Planning Commission, 1995). Forests cover a significant portion of the county and surround homes in many rural parts. Contact the Wallowa County Planning Department for specific requirements related to the county's land use plan.

3.5.1 Data sources

The Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results (PNRA; Pyrologix LCC, 2018) is a comprehensive report that includes a database developed by the United States Forest Service (USFS) for the states of Oregon and Washington. The steward of this database in Oregon is the Oregon Department of Forestry (ODF). The database was created to assess the level of risk residents and structures have to wildfire. For this project, the burn probability dataset, included in the PNRA database, was used to measure the risk to communities in Wallowa County.

Using guidance from ODF, we categorized the Burn Probability dataset into low, moderate, and high-hazard zones for the wildfire exposure analysis. Probability ranges of the Burn Probability dataset from the PNRA were grouped into 3 categories of wildfire hazard. Burn probability is derived from simulations using many elements, such as, weather, ignition frequency, ignition density, and fire modeling landscape (Pyrologix LCC, 2018).

Burn probabilities (mean annual burn probability) were grouped into 3 hazard categories:

- Low wildfire hazard (0.0001 – 0.0002 or 1/10,000 – 1/5,000)
- Moderate wildfire hazard (0.0002 – 0.002 or 1/5,000 – 1/500)
- High wildfire hazard (0.002 – 0.04 or 1/500 – 1/25)

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. In certain areas no wildfire data is present which indicates areas that have minimal risk to wildfire hazard (see **Appendix B**, Table B-8). We also estimated the number of people threatened by wildfire. Land value losses due to wildfire were not examined for this project.

3.5.2 Countywide results

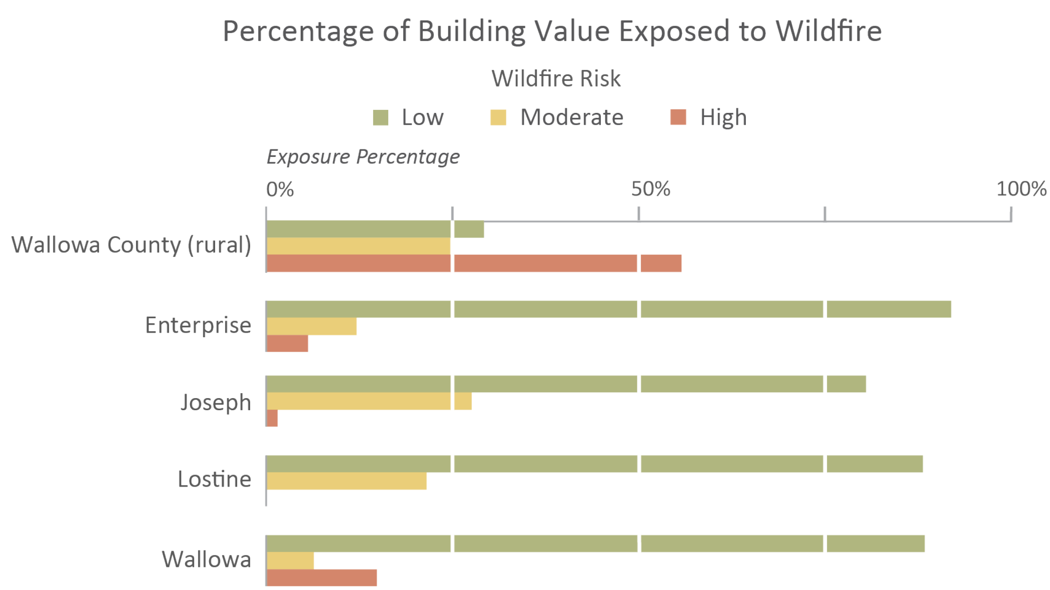
High wildfire hazard is present for a very large portion of the county but is moderate or low in the incorporated communities of the county, A high percentage (50%) of the buildings in the wildland urban interface and rural portions of the county are at significant risk to wildfire. While the risk is lower for the incorporated communities, exposure to moderate wildfire hazard is present in these areas and would result in a large amount of loss if they were to burn. Still, the focus of this section is on high hazard areas within Wallowa County to emphasize the areas where lives and property are most at risk. The total dollar value of exposed buildings in the study area is reported below.

Wallowa Countywide wildfire exposure (High hazard):

- Number of buildings: 3,623
- Value of exposed buildings: $285,948,000
- Percentage of total county value exposed: 31%
- Critical facilities exposed: 10
- Potentially displaced population: 1,473

3,491 buildings in Unincorporated Wallowa County (rural) are exposed to high wildfire hazard, but the incorporated communities have far less exposure to the high-risk category. The primary areas of exposure to this hazard are in the forested unincorporated areas throughout the county (see **Appendix E,** Plate 6). Enterprise and Wallowa have the highest percentage of exposure to high wildfire hazard for incorporated communities. **Figure 3-6** illustrates the level of risk from wildfire for the different communities of Wallowa County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-6. Wildfire hazard exposure by Wallowa County community.



3.5.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to wildfire hazard:

- Buildings throughout the unincorporated county are at high risk to wildfire.
- Buildings along the base of the Wallowa Mountains and along Wallowa Lake are at high risk to wildfire.
- Buildings in the northwestern portion of the City of Enterprise and the southern portion of the City of Wallowa are at high risk to wildfire.

4.0 CONCLUSIONS

The purpose of this study is to provide a better understanding of potential impacts from multiple natural hazards at the community scale. We accomplished this by using the latest natural hazard mapping and loss estimation tools to quantify expected damage to buildings and potential displacement of permanent residents, or determine which buildings and residents are exposed to a hazard. This comprehensive and detailed approach to the analysis provides new context for the county's risk reduction efforts. We note several important findings based on the results of this study:

- **Moderate overall damage and losses can occur from an earthquake—**Based on the results of a 2,500-year probabilistic Mw 7.0 earthquake, every community in Wallowa County will experience a moderate impact and disruption. Results show that an earthquake can cause building losses of 10% to 20% to all communities in the study area. Some communities like Enterprise and Wallowa can expect a high percentage of losses due to ground deformation related to liquefaction. The high vulnerability of the building inventory (building age and building type) and the number of buildings constructed on liquefiable soils contribute to the estimated levels of losses expected in the study area.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake shaking—**Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We examined potential loss reduction from seismic retrofits (modifications that improve building's seismic resilience) in simulations by using Hazus-MH building code "design level" attributes of pre, low, moderate, and high codes (FEMA, 2012b) in earthquake scenarios. The simulations were accomplished by upgrading every pre (non-existent) and low seismic code building to moderate seismic code levels in one scenario, and then by upgrading all buildings to high (current) code in another scenario. We found that retrofitting to at least moderate code was the most cost-effective mitigation strategy because the additional benefit from retrofitting to high code was minimal. In our simulation of upgrading buildings to at least moderate code, the estimated loss for the entire study area was reduced from 13% to 9.2%. We found only a slight reduction in estimated loss in our simulation to 8.9% by upgrading all buildings to high code. In both cases the gains are small in comparison to the considerable cost of retrofits, and retrofits may only make sense for critical facilities and high-occupancy buildings. Some communities would see greater loss reduction than the county on a whole, due to older building stock constructed at pre or low code seismic building code standards. An example is the City of Enterprise where a significant loss reduction (from 20% to 15%) could occur by retrofitting all buildings to at least moderate code. This stands in contrast to areas with younger building stock, such as the unincorporated county areas around the Cities of Enterprise and Joseph, which would see small reductions in damage estimates. While seismic retrofits are an

effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced landslide and liquefaction hazards will also be present in some areas, and these hazards require different geotechnical mitigation strategies. Future risk assessments focused on coseismic landslide and liquefaction hazards would provide a clearer understanding for local decision-makers.

- **Some communities in the county are at significant risk from flooding**—Most of buildings in Wallowa County are built along the Wallowa River and some of its tributaries that are prone to flooding. Flooding can also occur in several other rivers in the county that do not have an available stream model and were not included in this risk assessment. Current flood mapping in use is nearly 35 years old and may be inaccurate in its characterization of the 100-year flood. At first glance, Hazus-MH flood loss estimates may give a false impression of lower risk because they show lower damages for a community relative to other hazards we examined. This is due to the difference between loss estimation and exposure results, as well as the limited area impacted by flooding. Another consideration is that flood is one of the most frequently occurring natural hazards. An average of 3.8% loss was calculated when looking at just the buildings within the 100-year flood zone. The areas that are most vulnerable to flood hazard within the study are some residential buildings in Enterprise and Wallowa along the Wallowa River and some of its tributaries.
- **Elevating structures in the flood zone reduces vulnerability—**Flood exposure analysis was used in addition to Hazus-MH loss estimation to identify buildings that were not damaged but that were within the area expected to experience a 100-year flood. By using both analyses in this way, the number of elevated structures within the flood zone could be quantified. This showed possible mitigation needs in flood loss prevention and the effectiveness of past activities. The flood depth maps show that floods would occur over a wide area but would be relatively shallow, so that, many buildings exposed to flood hazard would be above the flood elevation. The City of Enterprise has a very high number (161) of buildings in the flood hazard area that are higher than the base flood elevation (BFE). Based on the number of buildings exposed to flooding throughout the unincorporated county, many would benefit from elevating above the level of flooding. Updated flood mapping would help to accurately determine the correct elevation required.
- **New landslide mapping would increase the accuracy of estimating landslide risk—**The landslide hazard data used in this risk assessment was created before the advent of modern mapping technology; future risk assessments using lidar-derived landslide hazard data would provide more accurate results.
- **Wildfire risk is very high for the overall study area—**Exposure analysis shows that buildings throughout the unincorporated county are vulnerable to wildfire hazard. The City of Wallowa is at risk to wildfire with 14% of the buildings in the high-risk zone. All communities in Wallowa County have some risk to wildfire with around 20% of buildings being in moderate or high wildfire risk zones.
- **Most of the study area's critical facilities are at significant risk to earthquake and wildfire hazards—**Critical facilities were identified and were specifically examined for this report. We estimate that 48% (19 of 40) of Wallowa County's critical facilities will be non-functioning after a 2,500-year probabilistic earthquake. Additionally, 25% (10 of 40) of critical facilities are exposed to high wildfire risk and 10% (4 of 40) to very high or high landslide hazard. We found no exposure of critical facilities to flood.

- **The biggest causes of displacement to population are earthquake and wildfire hazards—** Potential displacement of permanent residents from natural hazards was estimated in this report. We estimate that 21% of the population in the county could be displaced due a wildfire. Earthquake hazard is a potential threat to 8.2% of the population and flood hazard puts 8.9% at risk of displacement. A small percentage of residents are vulnerable to displacement from landslide hazard.
- **The results allow communities the ability to compare across hazards and prioritize their needs—**Each community within the study area was assessed for natural hazard exposure and loss. This allowed for comparison of risk for a specific hazard between communities. It also allows for a comparison between different hazards, though care must be taken to distinguish loss estimates and exposure results. The loss estimates and exposure analyses can assist in developing plans that address the concerns for those individual communities.

5.0 LIMITATIONS

There are several limitations to keep in mind when interpreting the results of this risk assessment.

- **Spatial and temporal variability of natural hazard occurrence** – Flood, earthquake, landslide, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones. For example, areas mapped in the 1% annual chance flood zone will be prone to flooding on occasion in certain watersheds during specific events, but not all at once throughout the entire county or even the entire community. While we report the overall impacts of a given hazard scenario, the losses from a single hazard event probably will not be as severe and widespread.
- **Loss estimation for individual buildings** – Hazus-MH is a model of reality, which is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevation of buildings to avoid flood loss, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and un-reinforced masonry buildings. Loss estimation is most insightful when individual building results are aggregated to the community level because it reduces the impact of uncertainty in building characteristics.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards (described above) and the inability to perform loss estimations due to the lack of Hazus-MH damage functions. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not make estimates about the level to which an individual building could be damaged or how many buildings might be impacted in a single event. Even a large wildfire would only cover a small part of the county at any time and most landslides would be unique events.
- **Population variability** – Some of the communities in Wallowa County have a number of vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on permanent populations published in the 2010 U.S. Census (United States Census Bureau, 2010b). As a result, we are slightly underestimating the number of people that may be in harm's way on a summer weekend.

- **Data accuracy and completeness** – Some datasets in our risk assessments had incomplete coverage or lacked high-resolution data within the study area. We used lower-resolution data to fill gaps where there was incomplete coverage or where high-resolution data were not available. Assumptions to amend areas of incomplete data coverage were made based on reasonable methods described within this report. However, we are aware that some uncertainty has been introduced from these data amendments at an individual building scale. At community-wide scales the effects of the uncertainties are lower. Data layers in which assumptions were made to fill gaps are building footprints, population, some building specific attributes, and landslide susceptibility. Many of the datasets included known or suspected artifacts, omissions and errors, identifying or repairing these problems was beyond the scope of the project and are areas needing additional research.

6.0 RECOMMENDATIONS

The following areas of implementation are needed to better understand hazards and reduce risk to natural hazard through mitigation planning. These implementation areas, while not comprehensive, touch on all phases of risk management and focus on awareness and preparation, planning, emergency response, mitigation funding opportunities, and hazard-specific risk reduction activities.

6.1 Awareness and Preparation

Awareness is crucial to lowering risk and lessening the impacts of natural hazards. When community members understand their risk and know the role that they play in preparedness, the community in general is a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the time a community needs to recover from a disaster, commonly referred to as "resilience."

This report is intended to provide local officials a comprehensive and authoritative profile of natural hazard risk to underpin their public outreach efforts.

Messaging can be tailored to stakeholder groups. For example, outreach to homeowners could focus on actions they can take to reduce risk to their property. The DOGAMI Homeowners Guide to Landslides (https://www.oregongeology.org/Landslide/ger_homeowners_guide_landslides.pdf) provides a variety of risk reduction options for homeowners who live in high landslide susceptibility areas. This guide is one of many existing resources. Agencies partnering with local officials in the development of additional effective resources could help reach a broader community and user groups.

6.2 Planning

The information presented here can help local decision-makers in developing their local plans and help identify geohazards and associated risks to the community. The primary framework for accomplishing this is through the comprehensive planning process. The comprehensive plan sets the long-term trajectory of capital improvements, zoning, and urban growth boundary expansion, all of which are planning tools that can be used to reduce natural hazard risk.

Another framework is the natural hazard mitigation plan (NHMP) process. NHMP plans focus on characterizing natural hazard risk and identifying actions to reduce risk. Additionally, the information presented here can be a resource when updating the mitigation actions and inform the vulnerability assessment section of the NHMP plan.

While there are many similarities between this report and an NHMP, the hazards or critical facilities in the two reports can vary. Differences between the reports may be due to data availability or limited methodologies for specific hazards. The critical facilities considered in this report may not be identical to those listed in a typical NHMP due to the lack of damage functions in Hazus-MH for non-building structures and to different considerations about emergency response during and after a disaster.

6.3 Emergency Response

Critical facilities will play a major role during and immediately after a natural disaster. This study can help emergency managers identify vulnerable critical facilities and develop contingencies in their response plans. Additionally, detailed mapping of potentially displaced residents can be used to re-evaluate evacuation routes and identify vulnerable populations to target for early warning.

The building database that accompanies this report presents many opportunities for future pre-disaster mitigation, emergency response, and community resilience improvements. Vulnerable areas can be identified and targeted for awareness campaigns. These campaigns can be aimed at pre-disaster mitigation through, for example, improvements of the structural connection of a building's frame to its foundation. Emergency response entities can benefit from the use of the building dataset through identification of potential hazards and populated buildings before and during a disaster. Both reduction of the magnitude of the disaster and a decrease in the response time contribute to a community's overall resilience.

6.4 Mitigation Funding Opportunities

Several funding options are available to communities that are susceptible to natural hazards and have specific mitigation projects they wish to accomplish. State and federal funds are available for projects that demonstrate cost effective natural hazard risk reduction. The Oregon Office of Emergency Management (OEM) State Hazard Mitigation Officer (SHMO) can provide communities assistance in determining eligibility, finding mitigation grants, and navigating the mitigation grant application process.

At the time of writing this report, FEMA has two programs that assist with mitigation funding for natural hazards: Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) Grant Program. FEMA also has a grant program specifically for flooding called Flood Mitigation Assistance (FMA). The SHMO can help with finding further opportunities for earthquake and tsunami assistance and funding.

6.5 Hazard-Specific Risk Reduction Actions

6.5.1 Earthquake

- Evaluate critical facilities for seismic preparedness by identifying structural deficiencies and vulnerabilities to dependent systems (e.g., water, fuel, power).
- Evaluate vulnerabilities of critical facilities. We estimate that 50% of critical facilities (**Appendix A: Community Risk Profiles**) will be damaged by an earthquake scenario described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.

- Identify communities and buildings that would benefit from seismic upgrades.

6.5.2 Flood

- Map areas of potential flood water storage.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.

6.5.3 Landslide

- Create modern landslide inventory and susceptibility maps.
- Monitor ground movement in high susceptibility areas.
- Consider land value losses due to landslide in future risk assessments.

6.5.4 Wildfire-related geologic hazards

- Evaluate post-wildfire geologic hazards including flood, debris flows, and landslides.

6.5.5 Channel migration

- Create modern channel migration hazard maps.
- Consider land value losses due to channel migration in future risk assessments.

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9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILES

A risk analysis summary for each community is provided in this section to encourage ideas for natural hazard risk reduction. Increasing disaster preparedness, public hazards communication, and education, ensuring functionality of emergency services, and ensuring access to evacuation routes are actions that every community can take to reduce their risk. This appendix contains community specific data to provide an overview of the community and the level of risk from each natural hazard analyzed. In addition, for each community a list of critical facilities and assumed impact from individual hazards is provided.

A.1 Unincorporated Wallowa County (Rural)

Table A-1. Unincorporated Wallowa County (rural) hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Unincorporated Wallowa County (rural)	2,966	6,472	16	523,679,000	

Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	101	3.4%	115	0	477,000	0.1%
Earthquake	2500-year Probabilistic	148	5.0%	966	5	48,629,035	9.3%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	185	6.2%	516	4	58,757,000	11.2%
Wildfire	High Hazard	1,315	44.3%	3,491	10	266,117,000	50.8%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-2. Unincorporated Wallowa County (rural) critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Hazard**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Communication Structure			X	X
Enterprise Water Treatment				
Howard Butte Lookout				X
Imnaha Christian Fellowship			X	
Imnaha Elementary				X
Imnaha Store and Tavern				X
Joseph State Airport		X		
Joseph Water Treatment			X	
Lazy F Ranch Airport				X
Memaloose Airport				X
ODFW Hatchery		X		X
Oregon State Police		X		
Reds Wallowa Horse Ranch Airstrip			X	X
Troy Elementary				X
Wallowa County Public Works		X		
Wallowa Lake Fire Station		X		X

A.2 City of Enterprise

Table A-3. City of Enterprise hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Enterprise		1,940	1,424		13	212,587,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	503	25.9%	163	0	794,000	0.4%
Earthquake	2500-year Probabilistic	282	14.5%	584	6	42,500,674	20.0%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	56	2.9%	45	0	8,101,000	3.8%
Wildfire	High Hazard	49	2.5%	43	0	10,894,000	5.1%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with “First floor height” above the level of flooding (base flood elevation).

Table A-4. City of Enterprise critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Cloverleaf Hall		X		
Enterprise Community Connections				
Enterprise Fire Department		X		
Enterprise High School		X		
Enterprise Maintenance Station Grounds				
Enterprise Municipal Airport				
Enterprise Safeway		X		
Enterprise SDA School				
Enterprise Sports Complex				
Wallowa County Courthouse		X		
Wallowa County Sheriff and Emergency Services				
Wallowa Memorial Hospital				
Wallowa Resources		X		

A.3 City of Joseph

Table A-5. City of Joseph hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Joseph	1,081	896	3	99,947,000

Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	2500-year Probabilistic	55	5.1%	172	1	10,188,975	10.2%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	1	0.1%	4	0	189,000	0.2%
Wildfire	High Hazard	9	0.8%	8	0	1,395,000	1.4%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-6. City of Joseph critical facilities.

	Flood 1% Annual Chance	**Earthquake Moderate to Complete Damage**	**Landslide High and Very High Susceptibility**	**Wildfire High Hazard**
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Joseph Fire Department				
Joseph High School				
Wallowa Mountain Office		X		

A.4 City of Lostine

Table A-7. City of Lostine hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Lostine	213	236	4	17,930,000

Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	0	0	0	0.0%
Earthquake	2500-year Probabilistic	3	1.6%	31	4	1,432,368	8.0%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	2	1.2%	2	0	276,000	1.5%
Wildfire	High Hazard	0	0.0%	0	0	0	0.0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-8. City of Lostine critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Lostine City Hall		X		
Lostine Fire Dept		X		
M Crow General Store		X		
Southfork Grange		X		

A.5 City of Wallowa

Table A-9. City of Wallowa hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Wallowa	808	680	4	55,658,000	

Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	19	2.3%	17	0	275,000	0.5%
Earthquake*	2500-year Probabilistic	88	10.9%	258	3	11,360,070	20%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	4	0.4%	1	0	123,000	0.2%
Wildfire	High Hazard	100	12.4%	81	0	7,542,000	14%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation).

Table A-10. City of Wallowa critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Wallowa Fire Dept.		X		
Wallowa High/Elementary School		X		
Wallowa Senior Center				
Wallowa Water Treatment		X		

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Wallowa County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Non-Profit			All Buildings			
Community	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Number of Buildings per Watershed Total	Building Value ($)	Value of Buildings per Watershed Total
Unincorp. Wallowa Co (rural)	2,627	368,343	70%	546	30,627	5.8%	3,250	107,323	20%	49	17,386	3.3%	6,472	66.7%	523,679	57.6%
Enterprise	898	118,457	56%	300	71,409	33.6%	202	5,376	2.5%	24	17,345	8.2%	1,424	14.7%	212,587	23.4%
Joseph	611	74,050	74%	136	13,323	13.3%	138	3,322	3.3%	11	9,252	9.3%	896	9.2%	99,947	11.0%
Lostine	128	14,015	78%	27	2,030	11%	74	1,235	6.9%	7	650	3.6%	236	2.4%	17,930	2.0%
Wallowa	437	40,545	73%	101	4,411	7.9%	126	2,754	4.9%	16	7,947	14.3%	680	7%	55,658	6%
Total Wallowa County	4,701	615,410	68%	1,110	121,801	13.4%	3,790	120,010	13.2%	107	52,580	6%	9,708	100.0%	909,800	100.0%

Table B-2. Earthquake loss estimates.

(all dollar amounts in thousands)

	Total Number of Buildings	Total Estimated Building Value ($)	Total Earthquake Damage: Buildings Damaged: Yellow-Tagged Buildings	Buildings Damaged: Red-Tagged Buildings	Buildings Damaged: Sum of Economic Loss	Buildings Damaged: Loss Ratio	All Buildings Changed to At Least Moderate Code: Yellow-Tagged Buildings	All Buildings Changed to At Least Moderate Code: Red-Tagged Buildings	All Buildings Changed to At Least Moderate Code: Sum of Economic Loss	All Buildings Changed to At Least Moderate Code: Loss Ratio
Unincorp. Wallowa Co (rural)	6,472	523,679	739	228	48,629	9.3%	606	136	37,524	7%
Enterprise	1,424	212,587	418	166	42,501	20%	341	73	31,114	15%
Joseph	896	99,947	138	34	10,189	10%	77	14	6,350	6%
Lostine	236	17,930	28	3	1,432	8%	8	1	636	4%
Wallowa	680	55,658	192	66	11,360	20%	151	33	8,123	15%
Total Wallowa County	9,708	909,800	1,515	497	114,111	13%	1,183	256	83,747	9%

Table B-3. Flood loss estimates.

			(all dollar amounts in thousands)											
			10% (10-yr)			**2% (50-yr)**			**1% (100-yr)**			**0.2% (500-yr)**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**
Unincorp. Wallowa Co (rural)	6,472	523,679	76	315	0.06%	109	415	0.1%	115	477	0.1%	142	629	0.1%
Enterprise	1,424	212,587	85	219	0.10%	142	664	0.31%	163	794	0.37%	243	1,450	0.68%
Joseph	896	99,947	0	0	0.0%	0	0	0.0%	0	0	0.0%	1	32	0.0%
Lostine	236	17,930	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Wallowa	680	55,658	6	29	0.1%	11	180	0.3%	17	275	0.5%	24	350	0.6%
Total Wallowa County	9,708	909,800	167	562	0.1%	262	1,259	0.1%	295	1,547	0.2%	410	2,461	0.3%

Table B-4. Flood exposure.

			1% (100-yr)				
Community	**Total Number of Buildings**	**Total Population**	**Potentially Displaced Residents from Flood Exposure**	**% Potentially Displaced Residents from flood Exposure**	**Number of Flood Exposed Buildings**	**% of Flood Exposed Buildings**	**Number of Flood Exposed Buildings Without Damage**
Unincorp. Wallowa Co (rural)	6,472	2,966	101	3.4%	141	2.2%	26
Enterprise	1,424	1,940	503	25.9%	324	22.8%	161
Joseph	896	1,081	0	0.0%	0	0.0%	0
Lostine	236	213	0	0.0%	0	0.0%	0
Wallowa	680	808	19	2.3%	21	3.1%	4
Total Wallowa County	9,708	7,008	622	8.9%	486	5.0%	191

Table B-5. Landslide exposure.

			(all dollar amounts in thousands)								
			Very High Susceptibility			**High Susceptibility**			**Moderate Susceptibility**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
Unincorp. Wallowa Co (rural)	6,472	523,679	20	1,662	0.3%	496	57,095	10.9%	2,365	193,176	37%
Enterprise	1,424	212,587	34	6,237	3%	11	1,863	0.9%	271	44,929	21%
Joseph	896	99,947	0	0	0.0%	4	189	0.2%	109	12,158	12%
Lostine	236	17,930	0	0	0.0%	2	276	1.5%	10	546	3%
Wallowa	680	55,658	0	0	0%	1	123	0.2%	82	6,555	12%
Total Wallowa County	9,708	909,800	54	7,899	0.9%	514	59,546	6.5%	2,837	257,364	28%

Table B-6. Wildfire exposure.

			(all dollar amounts in thousands)					
			High Hazard			**Moderate Hazard**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
Unincorp. Wallowa Co (rural)	6,472	523,679	3,491	266,117	51%	1,279	117,991	22.5%
Enterprise	1,424	212,587	43	10,894	5%	145	23,478	11%
Joseph	896	99,947	8	1,395	1%	237	25,150	25%
Lostine	236	17,930	0	0	0.0%	41	3,517	20%
Wallowa	680	55,658	81	7,542	14%	49	3,253	6%
Total Wallowa County	9,708	909,800	3,623	285,948	31.4%	1,751	173,389	19%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 4.2 and ArcGIS® Desktop® 10.7

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Wallowa County for use in both the flood and earthquake modules of Hazus-MH. The Wallowa County assessor database (acquired in 2021) was used to determine which tax lots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

The Oregon Department of Geology and Mineral Industries (DOGAMI) used the SBFO-1 (Williams, 2021) dataset to help precisely locate the centroid of each building. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. When buildings were partially within the inundation zone, the building point was moved to the centroid of the portion of the building within the inundation zone. An iterative approach was used to further refine locations of building points for the flood module by generating results, reviewing the highest value buildings, and moving the building point over a representative elevation on the lidar digital elevation model to ensure an accurate first floor height.

C.2.2 Attributing building points

Populating the required attributes for Hazus-MH was achieved through a variety of approaches. The Wallowa County assessor database was used whenever possible, but in many cases that database did not provide the necessary information. The following is list of attributes and their sources:

- **Longitude** and **Latitude** – Location information that provides Hazus-MH the x and y-position of the UDF point. This allows for an overlay to occur between the UDF point and the flood or earthquake input data layers. The hazard model uses this spatial overlay to determine the correct hazard risk level that will be applied to the UDF point. The format of the attribute must be in decimal degrees. A simple geometric calculation using GIS software is done on the point to derive this value.
- **Occupancy class** – An alphanumeric attribute that indicates the use of the UDF (e.g., 'RES1' is a single-family dwelling). The alphanumeric code is composed of seven broad occupancy types (RES = residential, COM = commercial, IND = industrial, AGR = agricultural, GOV = public, REL = non-profit/religious, EDU = education) and various suffixes that indicate more specific types. This code determines the damage function to be used for flood analysis. It is also used to attribute the Building Type field, discussed below, for the earthquake analysis. The code was interpreted from "Stat Class" or "Description" data found in the Wallowa County assessor database. When data was not available, the default value of RES1 was applied throughout.
- **Cost** – The replacement cost of an individual UDF. Loss ratio is derived from this value. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus database.

- **Year built** – The year of construction that is used to attribute the Building Design Level field for the earthquake analysis (see "Building Design" below). The year a UDF was built is obtained from Wallowa County assessor database. When not available, the year of "1900" was applied.
- **Square feet** – The size of the UDF is used to pro-rate the total improvement value for tax lots with multiple UDFs. The value distribution method will ensure that UDFs with the highest square footage will be the most expensive on a given tax lot. This value is also used to pro-rate the **Number of People** field for Residential UDFs within a census block. The value was obtained from DOGAMI's building footprints; where (RES) footprints were not available, we used the Wallowa County assessor database.
- **Number of stories** – The number of stories for an individual UDF, along with Occupancy Class, determines the applied damage function for flood analysis. The value was obtained from the Wallowa County assessor database when available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used for attribution.
- **Foundation type** – The UDF foundation type correlates with First Floor Height values in feet (see Table 3.11 in the Hazus-MH Technical Manual for the Flood Model [FEMA, 2012a]). It also functions within the flood model by indicating if a basement exists or not. UDFs with a basement have a different damage function from UDFs that do not have one. The value was obtained from the Wallowa County assessor database when available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used to ascertain if one exists or not.
- **First floor height** – The height in feet above grade for the lowest habitable floor. The height is factored during the depth of flooding analysis. The value is used directly by Hazus-MH, where Hazus-MH overlays a UDF location on a depth grid and using the **first floor height** determines the level of flooding occurring to a building. It is derived from the Foundation Type attribute or observation via oblique imagery or Google Street View™ mapping service.
- **Building type** – This attribute determines the construction material and structural integrity of an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information was unavailable from the Wallowa County assessor data, so instead it was derived from a statistical distribution based on **Occupancy class**.
- **Building design level** – This attribute determines the seismic building code for an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information is derived from the **Year Built** attribute (Wallowa County Assessor) and state/regional Seismic Building Code benchmark years.
- **Number of people** – The estimated number of permanent residents living within an individual residential structure. It is used in the post-analysis phase to determine the amount of people affected by a given hazard. This attribute is derived from default Hazus database (United States Census Bureau, 2010a) of population per census block and distributed across residential UDFs and adjusted based on population growth estimates from PSU Population Research Center.
- **Community** – The community that a UDF is within. These areas are used in the post-analysis for reporting results. The communities were based on incorporated area boundaries; unincorporated community areas were based on building density.

C.2.3 Seismic building codes

Oregon initially adopted seismic building codes in the mid-1970s (Judson, 2012). The established benchmark years of code enforcement are used in determining a "design level" for individual buildings. The design level attributes (pre code, low code, moderate code, and high code) are used in the Hazus-MH earthquake model to determine what damage functions are applied to a given building (FEMA, 2012b). The year built or the year of the most recent seismic retrofit are the main considerations for an individual design level attribute. Seismic retrofitting information for structures would be ideal for this analysis but was not available for Wallowa County. Table C-1 outlines the benchmark years that apply to buildings within Wallowa County.

Table C-1. Wallowa County seismic design level benchmark years.

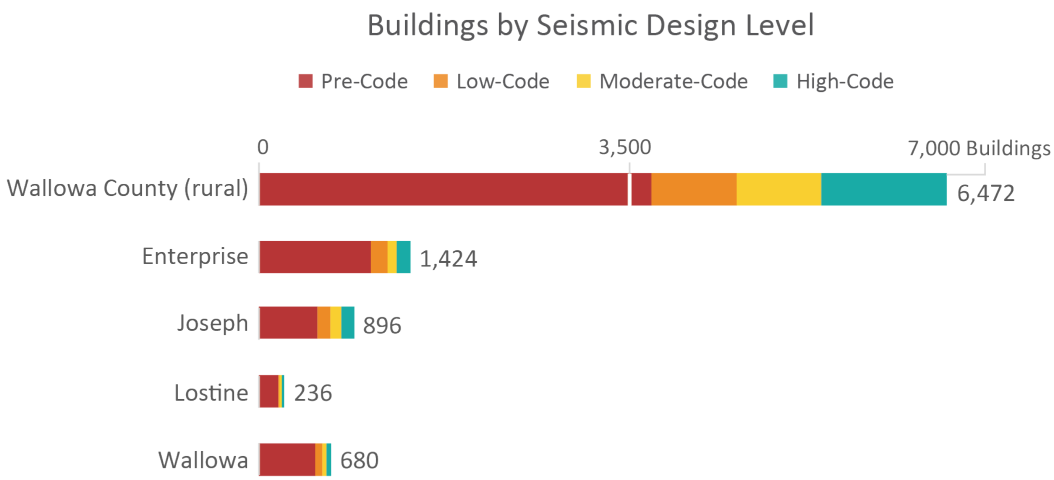
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured Dwelling Special Codes (Oregon Building Codes Division, 2002)
	2003–2010	Low Code	
	2011–2016	Moderate Code	Interpretation of OR BCD 2010 Manufactured Dwelling Special Codes Update (Oregon Building Codes Division, 2010)
All other buildings	prior to 1976	Pre Code	Business Oregon 2014-0311 Oregon Benefit-Cost Analysis Tool, p. 24 (Business Oregon, 2015)
	1976–1990	Low Code	
	1991–2016	Moderate Code	

Table C-2 and corresponding Figure C-1 illustrate the current state of seismic building codes for the county.

Table C-2. Seismic design level in Wallowa County.

Community	Total Number of Buildings	Pre Code: Number of Buildings	Pre Code: Percentage of Buildings	Low Code: Number of Buildings	Low Code: Percentage of Buildings	Moderate Code: Number of Buildings	Moderate Code: Percentage of Buildings	High Code: Number of Buildings	High Code: Percentage of Buildings
Unincorp. Wallowa Co (rural)	6,472	3,692	57%	804	12.4%	797	12.3%	1,179	18.2%
Enterprise	1,424	1,053	74%	155	11%	88	6%	128	9.0%
Joseph	896	550	61%	121	14%	103	11%	122	13.6%
Lostine	236	180	76%	11	4.7%	23	9.7%	22	9.3%
Wallowa	680	529	78%	67	10%	39	6%	45	6.6%
Total Wallowa County	9,708	6,004	62%	1,158	11.9%	1,050	10.8%	1,496	15.4%

Figure C-1. Seismic design level by Wallowa County community.



C.3 Flood Hazard Data

DOGAMI developed flood hazard data in 2021 from the Wallowa County FEMA Flood Insurance Study (FEMA, 1988). The hazard data was based on some previous flood studies and new riverine hydrologic and hydraulic analyses. For riverine areas, the flood elevations for the 100-year event for each stream cross-section were used to develop depth of flooding raster dataset or a “depth grid.”

A countywide, 2-meter, lidar-based depth grid was developed for each of the 10-, 50-, 100-, and 500-year annual chance flood events. The depth grids were imported into Hazus-MH for determining the depth of flooding for areas within the FEMA flood zones.

Once the UDF database was developed into a Hazus-compliant format, the Hazus-MH methodology was applied using a Python (programming language) script developed by DOGAMI. The analysis was then run for a given flood event, and the script cross-referenced a UDF location with the depth grid to find the depth of flooding. The script then applied a specific damage function, based on a UDF’s Occupancy Class [OccCls], which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF’s first-floor height.

C.4 Earthquake Hazard Data

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate permanent ground deformation and associated probability.

During the Hazus-MH earthquake analysis, each UDF was analyzed given its site-specific parameters (ground motion and ground deformation) and evaluated for loss, expressed as a probability of a damage state. Specific damage functions based on Building type and Building design level were used to calculate the damage states given the site-specific parameters for each UDF. The output provided probabilities of the five damage states (None, Slight, Moderate, Extensive, Complete) from which losses in dollar amounts were derived.

C.5 Post-Analysis Quality Control

Ensuring the quality of the results from Hazus-MH flood and earthquake modules is an essential part of the process. A primary characteristic of the process is that it is iterative. A UDF database without errors is highly unlikely, so this part of the process is intended to limit and reduce the influence these errors have on the final outcome. Before applying the Hazus-MH methodology, closely examining the top 10 largest area UDFs and the top 10 most expensive UDFs is advisable. Special consideration can also be given to critical facilities due to their importance to communities.

Identifying, verifying, and correcting (if needed) the outliers in the results is the most efficient way to improve the UDF database. This can be done by sorting the results based on the loss estimates and closely scrutinizing the top 10 to 15 records. If corrections are made, then subsequent iterations are necessary. We continued checking the “loss leaders” until no more corrections were needed.

Finding anomalies and investigating possible sources of error are crucial in making corrections to the data. A wide range of corrections might be required to produce a better outcome. For example, floating homes may need to have a first-floor height adjustment or a UDF point position might need to be moved due to issues with the depth grid. Incorrect basement or occupancy type attribution could be the cause of a problem. Commonly, inconsistencies between assessor data and tax lot geometry can be the source of an error. These are just a few of the many types of problems addressed in the quality control process.

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

CRS	Community Rating System
CSZ	Cascadia subduction zone
DLCD	Oregon Department of Land Conservation and Development
DOGAMI	Department of Geology and Mineral Industries (State of Oregon)
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FRI	Fire Risk Index
GIS	Geographic Information System
NFIP	National Flood Insurance Program
NHMP	Natural hazard mitigation plan
NOAA	National Oceanic and Atmospheric Administration
ODF	Oregon Department of Forestry
OEM	Oregon Emergency Management
OFR	Open-File Report
OPDR	Oregon Partnership for Disaster Resilience
PGA	Peak ground acceleration
PGD	Permanent ground deformation
PGV	Peak ground velocity
Risk MAP	Risk Mapping, Assessment, and Planning
SHMO	State Hazard Mitigation Officer
SLIDO	State Landslide Information Layer for Oregon
UDF	User-defined facilities
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WUI	Wildland-urban interface
WWA	West Wide Wildfire Risk Assessment

D.2 Definitions

1% annual chance flood – The flood elevation that has a 1-percent chance of being equaled or exceeded each year. Sometimes referred to as the 100-year flood.

0.2% annual chance flood – The flood elevation that has a 0.2-percent chance of being equaled or exceeded each year. Sometimes referred to as the 500-year flood.

Base flood elevation (BFE) – Elevation of the 1-percent-annual-chance flood. This elevation is the basis of the insurance and floodplain management requirements of the NFIP.

Critical facilities – Facilities that, if damaged, would present an immediate threat to life, public health, and safety. As categorized in HAZUS-MH, critical facilities include hospitals, emergency operations centers, police stations, fire stations and schools.

Exposure – Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.

Flood Insurance Rate Map (FIRM) – An official map of a community, on which FEMA has delineated both the SFHAs and the risk premium zones applicable to the community.

Flood Insurance Study (FIS) – Contains an examination, evaluation, and determination of the flood hazards of a community and, if appropriate, the corresponding water-surface elevations.

Hazus-MH – A GIS-based risk assessment methodology and software application created by FEMA and the National Institute of Building Sciences for analyzing potential losses from floods, hurricane winds, and earthquakes.

Lidar – A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Lidar is popularly used as a technology to make high-resolution maps.

Liquefaction – Describes a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually an earthquake, causing it to behave like liquid.

Loss Ratio – The expression of loss as a fraction of the value of the local inventory (total value/loss).

Magnitude – A scale used by seismologists to measure the size of earthquakes in terms of energy released.

Risk – Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard. Sometimes referred to as vulnerability.

Risk MAP – The vision of this FEMA strategy is to work collaboratively with State, local, and tribal entities to deliver quality flood data that increases public awareness and leads to action that reduces risk to life and property.

Riverine – Of or produced by a river. Riverine floodplains have readily identifiable channels.

Susceptibility – Degree of proneness to natural hazards that is determined based on physical characteristics that are present.

Vulnerability – Characteristics that make people or assets more susceptible to a natural hazard.

APPENDIX E. MAP PLATES

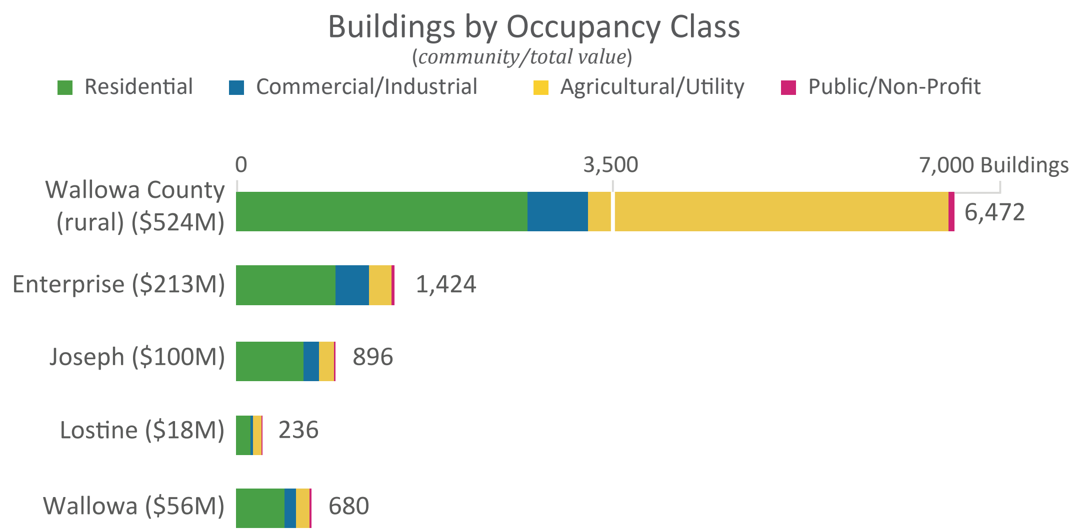
See appendix folder for individual map PDFs.

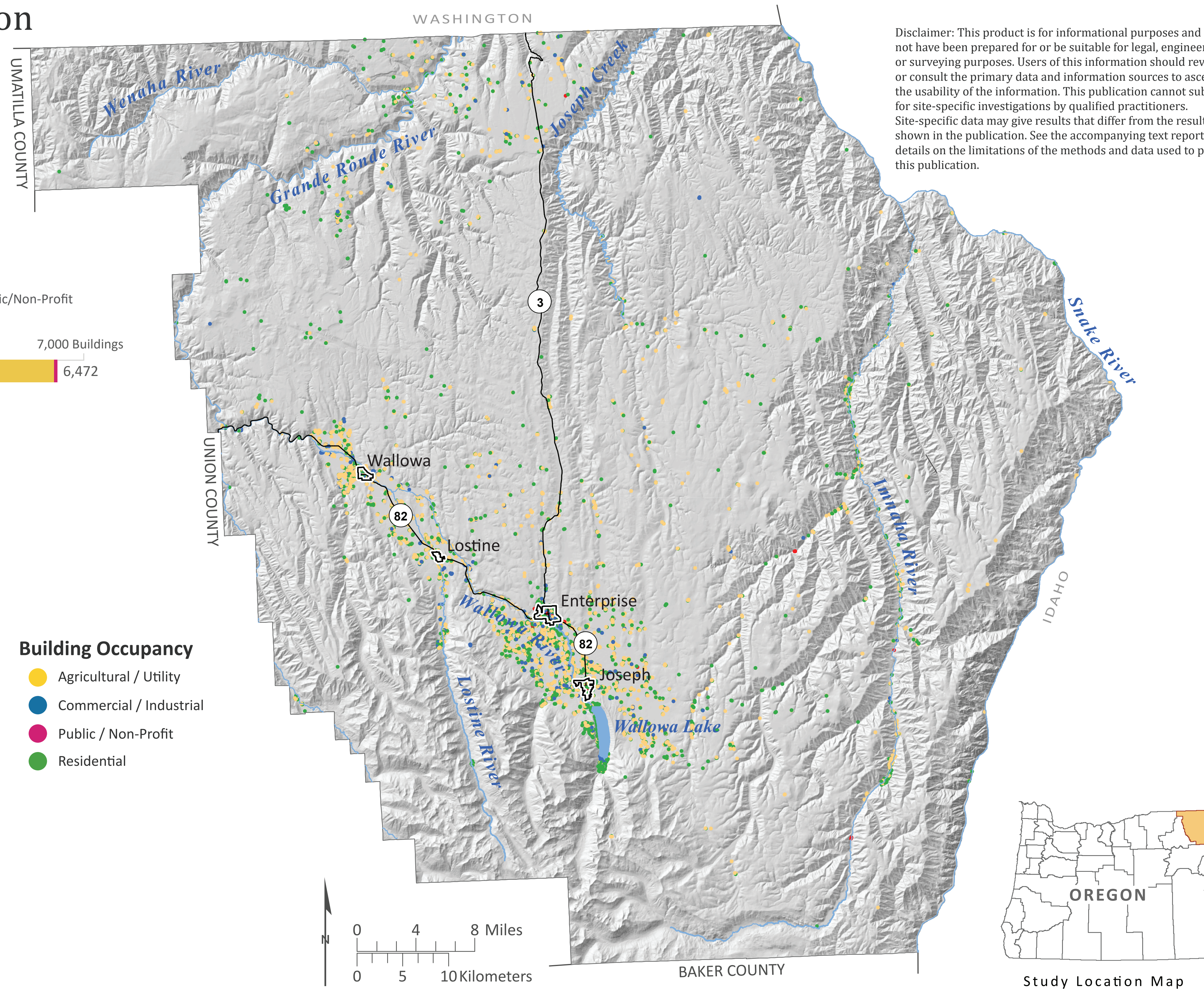
Building Distribution Map of Wallowa County, Oregon

PLATE 1

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Wallowa County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.





Data Sources:
Building footprints: Statewide Building Footprints of Oregon (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by: Matt C. Williams, 2021

Population Density Map of Wallowa County, Oregon

PLATE 2

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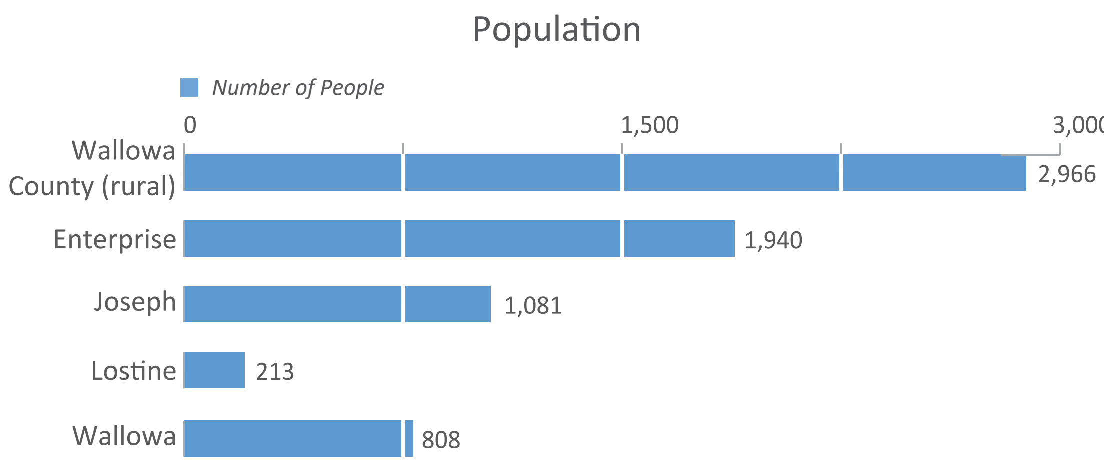

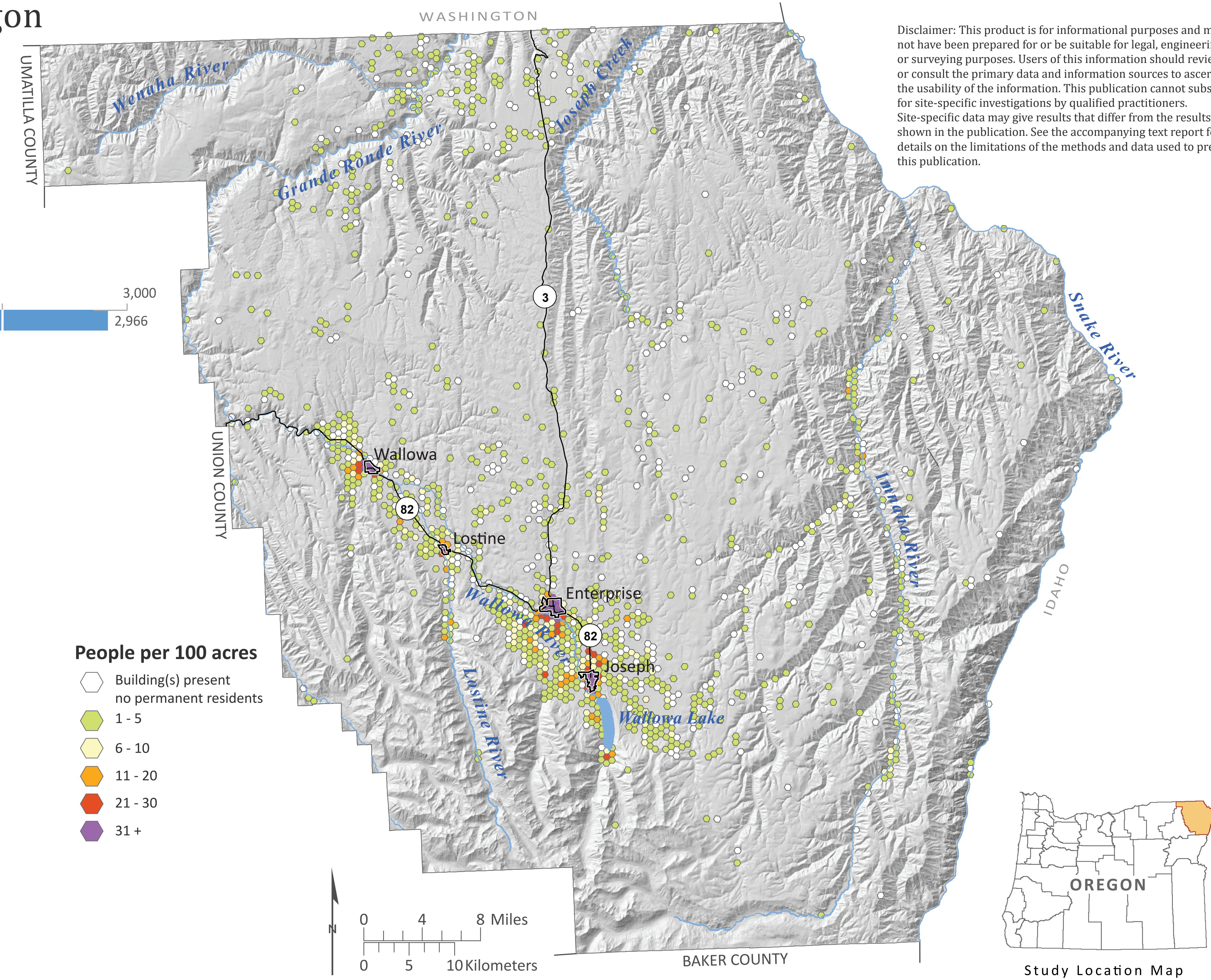

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Wallowa County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Data Sources:
Population: United States Census (2010)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by: Matt C. Williams, 2021

2,500-year Probabilistic Earthquake Shaking Map of Wallowa County, Oregon

PLATE 3

Peak Ground Acceleration (PGA) is the maximum acceleration in a given location or rather how hard the ground is shaking during an earthquake. It is one measurement of ground motion, which is closely associated with the level of damage that occurs from an earthquake.

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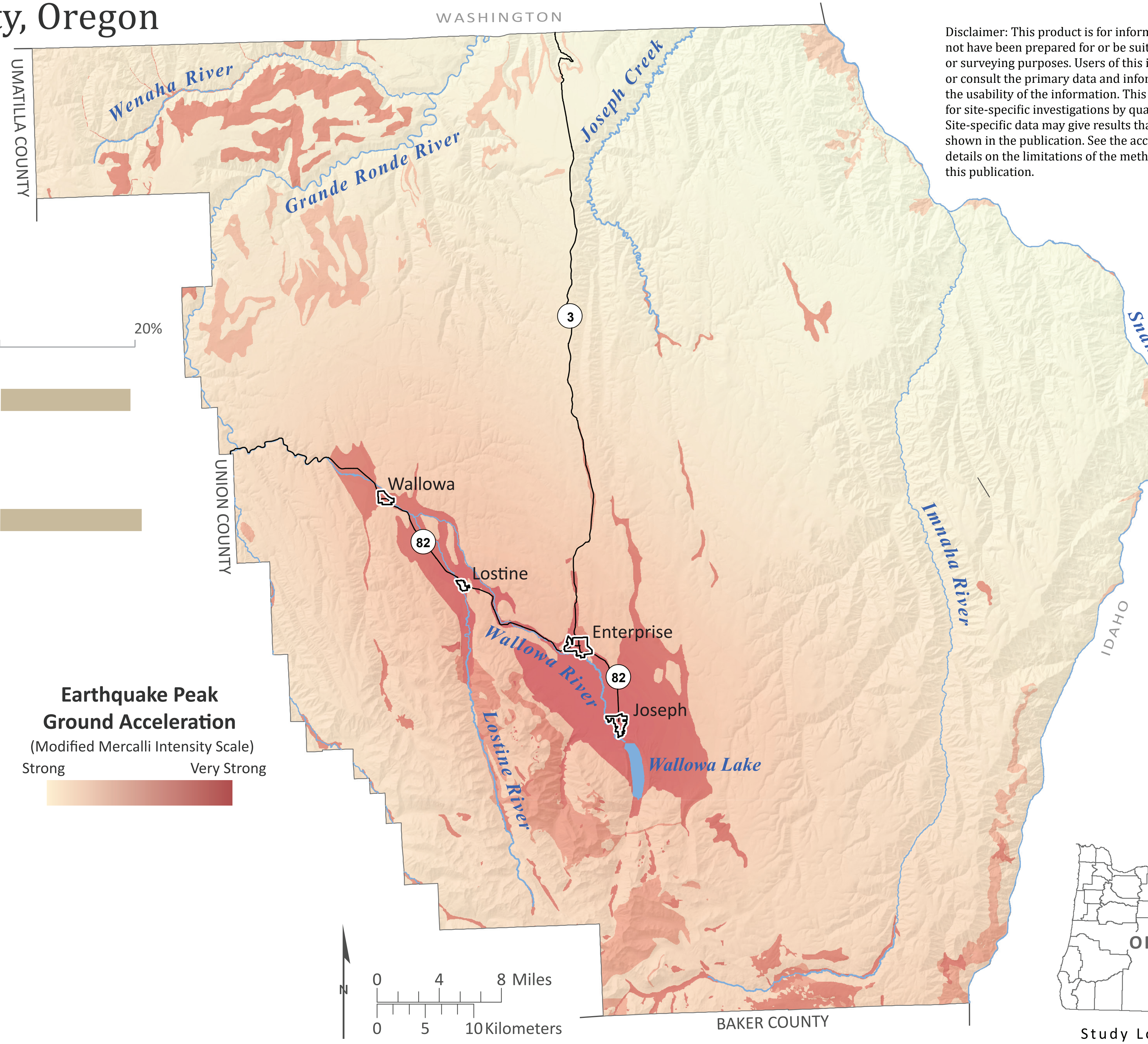
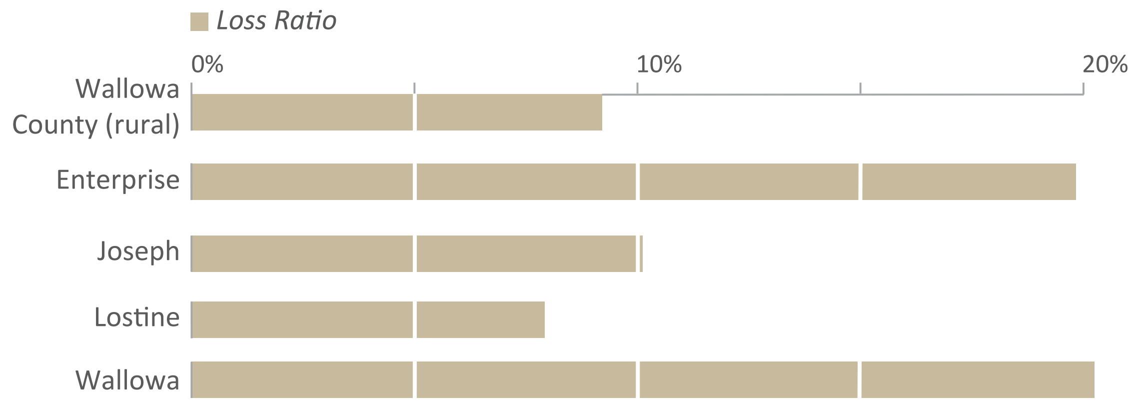


Total Building Value Loss Ratio From Mw 7.0 Earthquake



This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Wallowa County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Study Location Map

Data Sources:
Earthquake peak ground acceleration: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by: Matt C. Williams, 2021

PLATE 4

Flood Hazard Map of Wallowa County, Oregon

The flood hazard data show areas expected to be inundated during a 100-year flood event. Flooding sources are riverine in origin. Areas are consistent with the regulatory flood zones depicted in Wallowa County's Flood Insurance Rate Maps.

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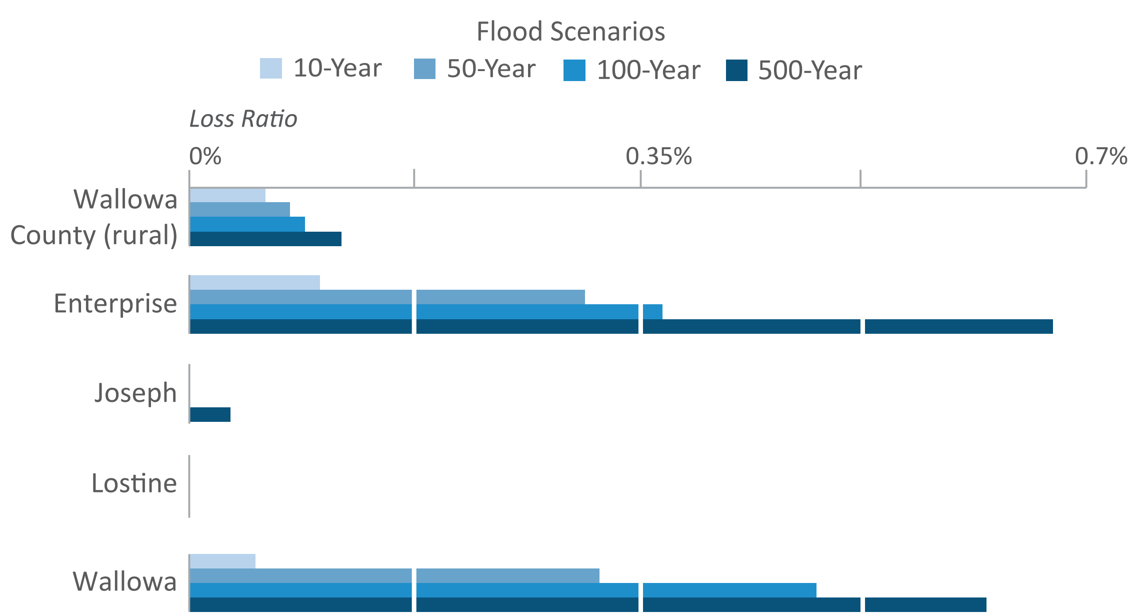
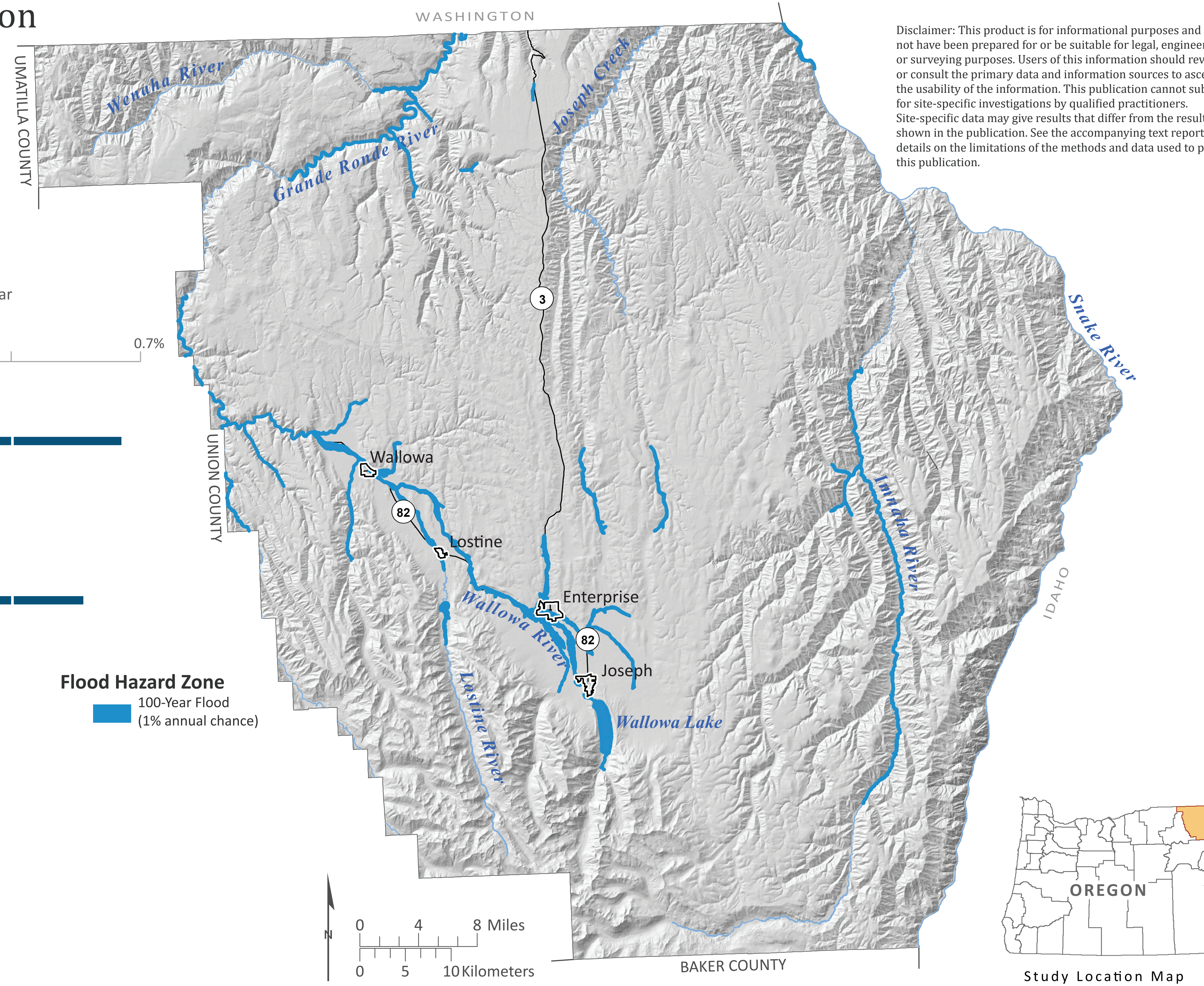
Ratio of Estimated Loss to Flooding





Study Location Map

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Wallowa County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Data Sources:
Flood hazard zone (100-year): Wallowa County Flood Insurance Rate Map (1988)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

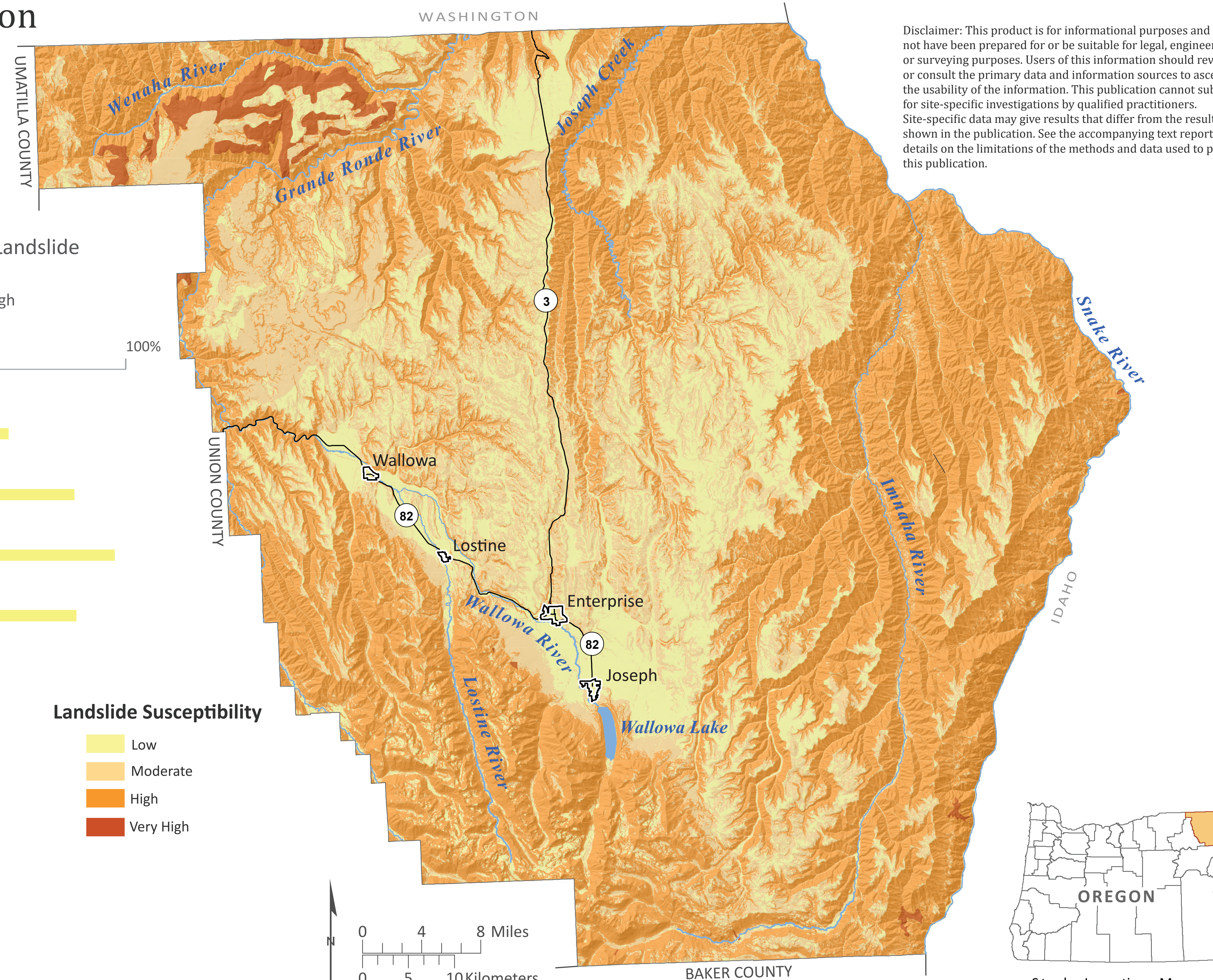
Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by: Matt C. Williams, 2021

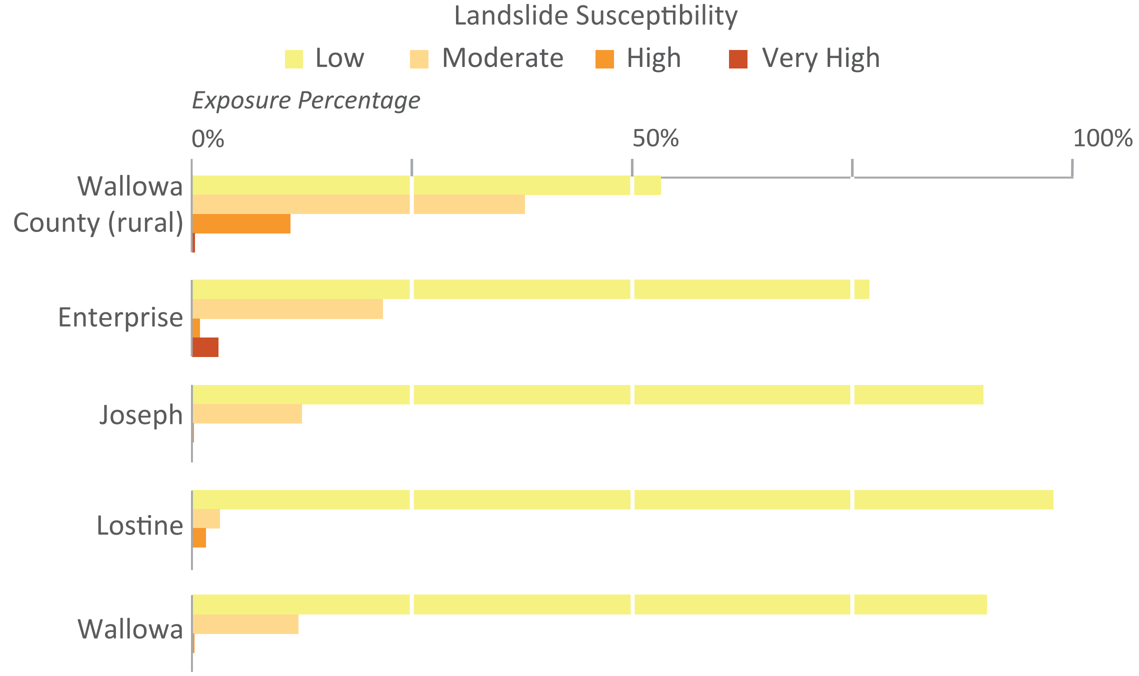
Landslide Susceptibility Map of Wallowa County, Oregon

PLATE 5

Landslide susceptibility is categorized as Low, Moderate, High, and Very High which describes the general level of susceptibility to landslide hazard. The dataset is an aggregation of three primary sources: landslide inventory (SLIDO), generalized geology, and slope.



Percentage of Building Value Exposed to Landslide



This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Wallowa County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Landslide Susceptibility

- Low
- Moderate
- High
- Very High

Study Location Map

Data Sources:
Landslide susceptibility: Oregon Department of Geology, Burns and others (2016)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

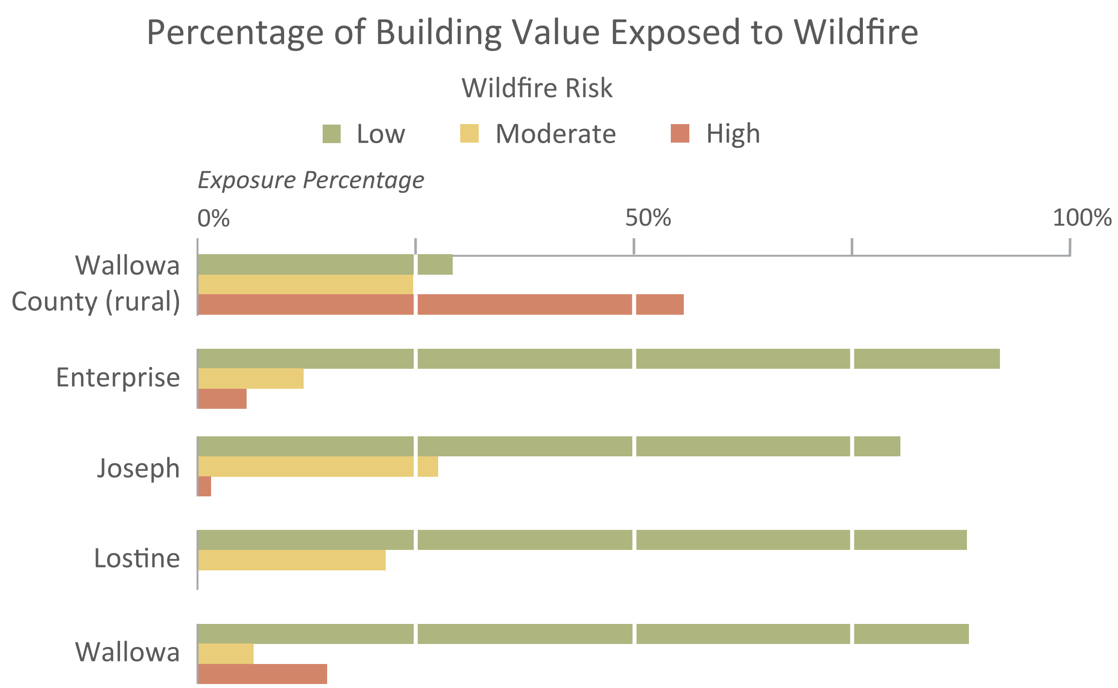
Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri® ArcMap 10, Adobe® Illustrator CC

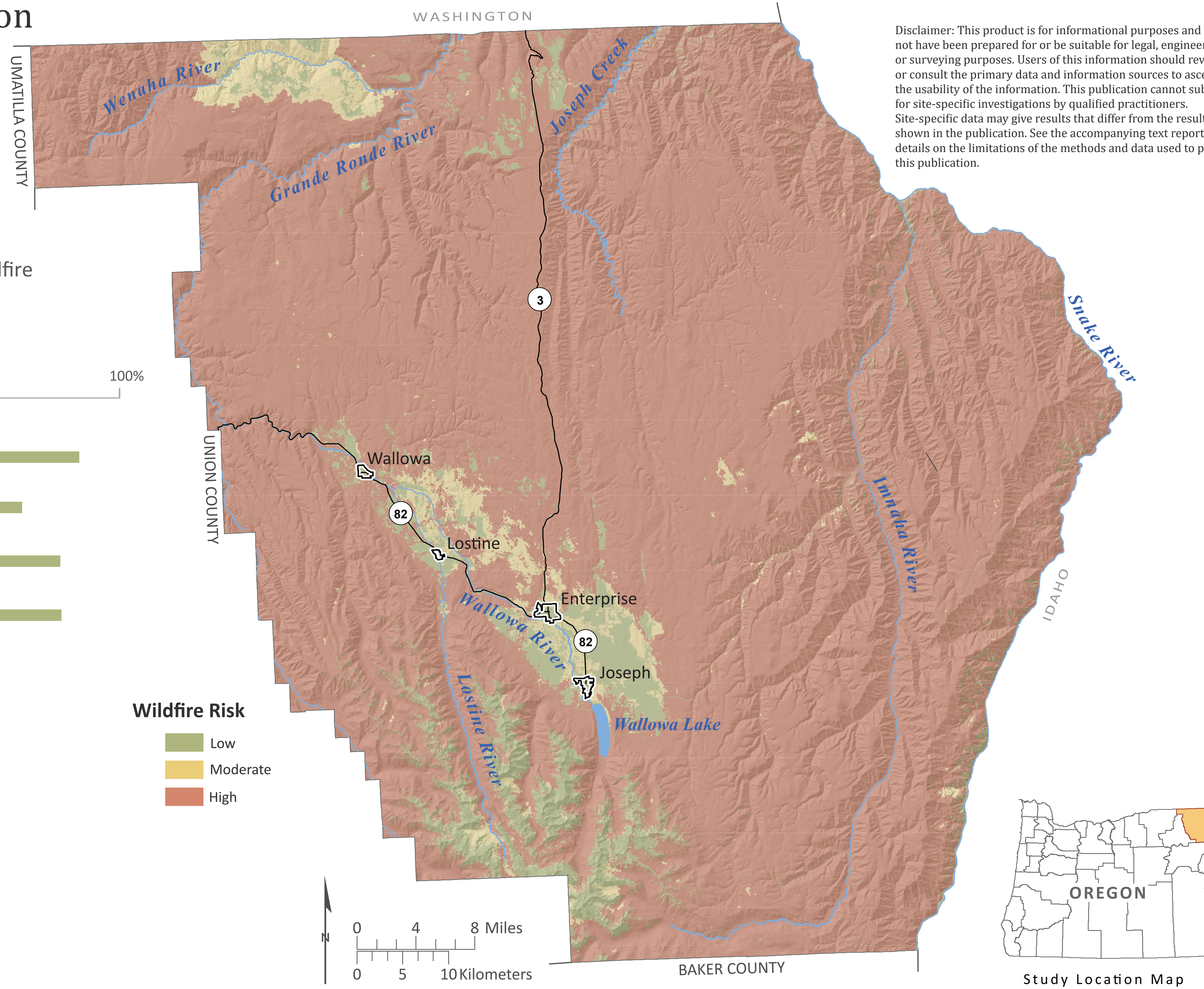
Cartography by: Matt C. Williams, 2021

PLATE 6

Wildfire Risk Map of Wallowa County, Oregon

The Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results (PNRA; Pyrologix LCC, 2018) is a comprehensive report that includes a database developed by the United States Forest Service for the states of Oregon and Washington. The PNRA produced the Burn Probability dataset that we used to calculate risk. The Burn Probability dataset was categorized into low, moderate, and high-hazard zones for the wildfire exposure analysis. Burn probability is derived from simulations using many elements, such as, weather, ignition frequency, ignition density, and fire modeling landscape.





Study Location Map

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Wallowa County Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Data Sources:
Wildfire risk data: Oregon Department of Forestry, Pyrologix, LCC. (2018)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by: Matt C. Williams, 2021